Mid-sized Mountain Streams

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Typology, Assessment and Reliability of Sampling and Assessment Methods

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The current that with gentle murmur glides,
Thou know´st, being stopped, impatiently does rage.
But when his fair course is not hindered
He makes sweet music with th´enamelled stones,
Giving a gentle kiss to every sedge
He overtaketh in his pilgrimage.
And so by many winding nooks he strays
With willing sport to the wild ocean.

[Julia in Act 2 in "The two Gentlemen of Verona"
(Shakespeare 1598 in Wells & Taylor 1988)]

Dedicated to my parents and the working group of Hydrobiology
at the University of Duisburg-Essen.

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Preface

Research in ecology is like an unending staircase, which widens up the more steps you take. The closer one approaches a solution for one scientific problem, the more unanswered ones turn up elsewhere. Streams of the mountainous areas of Germany and their inhabiting aquatic invertebrate fauna were the starting point of this thesis leading to several wider perspectives. Investigating these mountain streams reveals questions about their faunal characteristics compared to lowland rivers and to high alpine rivers and even about the variability between mountain streams. At the same time, statistical theory requires us to consider the reliability and repeatability of any research result.
The subsequent thesis consists of three chapters. Each chapter has its own self-contained introduction and sub-chapters on methods, results and discussion. Overall conclusions and a summary are given to integrate these pieces of research jigsaw.

In the first chapter, I will try to answer questions about differences in the aquatic biota between German lowland, mountain and alpine streams, but concentrating on the mountainous and alpine regions. There have been many publications on this topic (e.g. Huet 1946; Illies 1961; Braukmann 1987; Sommerhäuser 1998; LUA 1999b; Sommerhäuser & Schuhmacher 2003) but a comprehensive statistical evaluation based on the benthic invertebrate community has not yet been conducted. Filling this gap I started from two sides with two different data sets: (1) taxa lists from all parts of Germany applying a variety of sampling protocols; (2) a smaller number of taxa lists from certain regions of Germany applying a consistent sampling protocol. The taxonomic resolution of the first and larger data set is low (mainly genus level) compared to the second data set (species level). Within the first data set the taxa lists were reduced to just presence/absence level and only a subset of taxonomic groups was considered. In the second data set abundance data and the complete benthic invertebrate community were used instead. Linking abiotic parameters to the benthic invertebrate taxa lists helped to determine the major factors, which influence macroinvertebrates to inhabit a stream reach.
The question, which taxonomic resolution and data type is necessary to create stream typologies, is answered in a second step. A homogeneous data set in terms of sampling, sorting and identification was evaluated to identify the effects of different resolutions. Species level is compared to family level, using the complete taxa list is compared to using the taxonomic groups Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Odonata and

Mollusca (EPTCOM) and using logarithmically transformed abundances is compared to results based on presence/absence data.
The data sets of mid-sized and large mountain streams stimulated further research about differences in the occurrences and abundances of single species in a more precise analysis. Detecting key indicator species for these two stream types was the target. An analysis on species level compares the frequencies and abundances of the taxa present in near-natural sites of the two stream types.

However, the benthic invertebrate community of mid-sized mountain streams can differ significantly amongst streams. Variances in the morphology of stream reaches change the habitat and thus, the benthic invertebrate community. Consequently, the next question was to find criteria how to assess stream differences especially if they are man-made.
In Central European streams morphological monotony is apparent everywhere: single thread channels incised into a siltated floodplain, fixed channel banks prevent the (sideways) mobility of the streams (e.g. Figure 23 and Figure 24), the habitat diversity is extremely reduced. Thus, hydromorphological degradation is the present day norm and the major influence factor on aquatic life rather than organic pollution. This started the idea to detect and assess habitat degradation, fragmentation and the loss of habitats for the biota.
Assessment systems based on macroinvertebrates are very common around the world (e.g. Zelinka & Marvan 1961; Armitage et al. 1983; Plafkin et al. 1989; DEV 1992; Growns et al. 1997; Barbour et al. 1999) but they focus mainly on organic pollution. The special needs of biota in their habitat preference were summed up for several German species by Schmedtje & Colling (1996). Building an assessment system on these habitat preferences and autecological characteristics and identifying limits of biotic occurrence is the aim of chapter two. Focussing on mid-sized mountain streams in Germany an extensive field, lab and computer simulation study lead to a macroinvertebrate-based assessment system, whereby the species-habitat associations tell us about species needs for habitat conditions.

Assessment systems are always a matter of discussion (e.g. Chessman & McEnvoy 1998; Doberstein et al. 2000). Anticipating the need to justify sorting and assessment methods used led to the main question of the third chapter of this thesis: the statistical reliability of sampling and assessment methods. What, if the standard deviations of indices or metrics amongst macroinvertebrate samples exceed the widths of the individual quality classes derived by a site assessment method? How about smaller sample sizes (e.g. Courtemanch 1996)? Are adequately precise assessment results attainable with e.g. 100

organisms (e.g. Barbour et al. 1996)? Thus, in chapter three I will estimate the minimum numbers of macroinvertebrate organisms that need to be identified for an adequately reliable site assessment. The calculations focus on the assessment systems for three stream types: mid-sized sand bottom streams, small streams and mid-sized streams in lower mountainous areas. This leads to a recommendation for sample sizes in monitoring programs.

New trends in aquatic ecology look upon the shores of autecological studies, abiotic typologies, one-factorial assessments (e.g. saprobic situations) and mere statistical evaluations. The combination of these individual sciences into an applied ecological approach is the far-reaching objective of this thesis.

Hence, I would like to complete the circle of research components starting from the stream typology leading over to site assessment and ending with sample size recommendations. All of these aspects are related to the needs of the biota. The integrated results of this typology, assessment and testing of reliability will help monitoring streams and achieving the overall goal of stream restoration.

Definitions – Abbreviations

This thesis developed from a series of projects and is based on several key words, which are summarised and defined as follows:

AQEM-method

One of the main results of the AQEM-project (see below) was the development and application of a consistent sampling method (Hering et al. 2004). This so-called "Multi-Habitat-Sampling" is based on the "Rapid Bioassessment Protocol" of Barbour et al. (1998). 20 sample units have to be taken with a standardised shovel sampler (25 x 25 cm) according to the proportions of the substrates in a stream reach. The substrate estimation follows a standardised protocol (Hering et al. 2004), which ignores substrates with a coverage lower than 5 %.

AQEM-project [1]

The AQEM-project (www.aqem.de) was an European Union funded project lasting from March 2000 to February 2002. Scientific organisations and corresponding applied partners of eight European countries (Austria, Czech Republic, Germany, Greece, Italy, the Netherlands, Portugal and Sweden) conducted 941 macroinvertebrate samples in 28 common stream types throughout Europe using a consistent method. The main goal was to develop and test stream type and stressor specific assessment systems for the ecological quality of streams and rivers throughout Europe.

AQEM-software

A second main outcome of the AQEM-project was a computer program, which calculates the stream type specific assessment from a macroinvertebrate taxa list. The first version (2002; downloadable from www.aqem.de) contained assessment systems for all stream types examined in the AQEM-project. In April 2004 the program was updated (Version 2.3) with assessment systems for 22 German stream types.

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[1] The Development and Testing of an Integrated **A**ssessment System for the Ecological **Q**uality of Streams and Rivers throughout **E**urope using Benthic **M**acroinvertebrates. AQEM was funded by the European Commission, 5th Framework Program, Energy, Environment and Sustainable Development, Key Action 1 "Sustainable Management and Quality of Water"; Contract no. EVK1-CT1999-00027.

Assessment

The evaluation of the quality of a particular theme (in this case a stream reach) in respect to a reference status, e.g. the assessment according to the German national saprobic guidelines or the assessment according to the EU Water Framework Directive (see below). The criteria for the evaluation and the reference status have to be standardised.

Classification

Classification is the "general process of grouping entities by similarity" (Bailey 1994). It can be performed with various statistical methods, e.g. cluster analysis or "Non-metric Multidimensional Scaling" (NMS; see below). The grouping can be based upon abiotic (e.g. pH-value) or biotic (e.g. taxa lists) parameters. In stream ecology it is mainly used *a posteriori* to validate typologies, which had been proposed *a priori*.

EPTCOM

The macroinvertebrate taxonomic groups: **E**phemeroptera, **P**lecoptera, **T**richoptera, **C**oleoptera, **O**donata and **M**ollusca are very common in streams all over the world and well studied. This abbreviation is often used in macroinvertebrate related issues.

Indicator species analysis (IndVal)

This statistical method detects and calculates species indicator values. The frequency and the abundance of species in a particular group is calculated in respect to their frequency and abundance in other groups (Dufrêne & Legendre 1997). The indicator values are given for each species in each group and tested for statistical significance with a Monte Carlo technique.

LAWA-project [2]

The "Länderarbeitsgemeinschaft Wasser" (LAWA) funded at the University of Duisburg-Essen the German national project "Validation der Fließgewässertypologie Deutschlands" [Validation of the German stream typology] lasting from April 2002 to January 2004. Based upon an assignment of all streams with a catchment area larger than 10 km^2 to a stream type according to the top down typology of Schmedtje et al. (2001) seven stream types throughout Germany were sampled applying the AQEM-method (see above). The University

[2] The "**L**änder**a**rbeitsgemeinschaft **Wa**sser" is a German national consortium of representives of the water authorities of the Federal States. The project was funded under Contract no. O 3.02.

of Duisburg-Essen participated in this project co-ordinated by Peter Haase of the Research Institute Senckenberg and sampled three stream types with an overall number of 24 samples.

Non-metric Multidimensional Scaling (NMS)

NMS is a multivariate statistical method to depict the (dis)similarity of elements (e.g. macroinvertebrate samples) in a two- or three-dimensional diagram. The distance of the elements plotted in the diagram is calculated from a distance matrix, preferably using the Soerensen (Bray-Curtis) Index.

Mid-sized mountain streams

A stream type defined in the German stream typology (Schmedtje et al. 2001; Sommerhäuser & Pottgiesser 2004; Appendix 1 and 2). The main abiotic characteristic of this stream type is a catchment area between 100 and 1000 km^2. They occur in the mountainous areas of Germany and according to the German stream typology (Schmedtje et al. 2001; Sommerhäuser & Pottgiesser 2004) are restricted to altitudes ranging from 200 to 800 m above sea level. Macroinvertebrate samples of this stream type are in the centre of this thesis.

STAR-project [3]

STAR (www.eu-star.at) is the follow-up project of AQEM. It started in January 2002 and will terminate in December 2004. Six additional partners (Denmark, France, Great Britain, Latvia, Poland and Slovak Republic) joined the members of the AQEM-project. Based on the results of AQEM the consortium aims at developing a standardised sampling, sorting and assessment system for streams and rivers throughout Europe.

Typology

Typology is the conceptual grouping of entities based upon *a priori* and subjective judgements of class definitions and boundaries (Bailey 1994), e.g. the German stream typology of Schmedtje et al. (2001), which is based on ecoregional, geological, catchment size and substrate-related parameters.

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[3] **Sta**ndardisation of **R**iver Classifications: Framework method for calibrating different biological survey results against ecological quality classifications to be developed for the Water Framework Directive. STAR was funded by the European Commission, 5th Framework Program, Energy, Environment and Sustainable Development, Key Action 1 "Sustainable Management and Quality of Water", Contract no. EVK1-CT2001-00089.

UBA-project [4]

The German national project "Weiterentwicklung und Anpassung des nationalen Bewertungssystems für Makrozoobenthos an neue internationale Vorgaben" [Further development and adaptation of the national assessment system for macroinvertebrates to new international requirements] strives to develop macroinvertebrate-based assessment systems for 23 German stream types (according to Sommerhäuser & Pottgiesser 2004; Appendix 1 and 2). It started in April 2002 and will terminate in December 2004. The assessment systems should be stressor specific and reconcile with the EU Water Framework Directive (see below). These systems were developed with national monitoring data of the Federal States as well as with new samples conducted with the AQEM-method (see above). By correlating biotic metrics calculated with the macroinvertebrate taxa lists with abiotic parameters of the sampling sites sets of metrics were extracted, which served best to assess particular stream types. The abiotic parameters were site related (hydromorphological features) as well as catchment area related (land use in the catchment).

EU Water Framework Directive (WFD)

On October 23rd 2000 the European Union passed the Water Framework Directive (Directive 2000/60/EC - Establishing a Framework for Community Action in the Field of Water Policy). This law claims, amongst other, that all streams in Europe have to be in a "good ecological status" before the year 2015. The evaluation and the assessment of the ecological status should be based on biological quality elements, namely macroinvertebrates, fish, phytobenthos, macrophytes or phytoplankton. Abiotic characteristics should only serve as additional parameters. Assessment systems are supposed to have five quality classes ranging from "high" over "good", "moderate" and "poor" to "bad" status.

[4] The "**U**mwelt**b**undes**a**mt" is the German national environmental authority, which leads and supports ecological research in Germany. The project was funded under Contract no. (UFOPLAN) 202 24 223.

1 Validation of the German stream typology using benthic invertebrates

Abstract

Based on benthic invertebrate samples from near-natural streams in Germany stream types and the necessary taxonomic resolution for typological questions were investigated. Key indicator taxa for two stream types were proposed.

390 samples from all over Germany were sampled with various protocols. Non-metric Multidimensional Scaling (NMS) served to define stream type groups. The taxa lists were restricted to Mollusca, Ephemeroptera, Odonata, Plecoptera, Coleoptera and Trichoptera species and evaluated on presence/absence level. At genus level, streams located in the lowlands differ from streams in lower mountainous areas and the Alps, while the two latter groups were found to be indistinguishable. At species level, streams in the Alps can be distinguished from streams in lower mountainous areas. Within the lower mountainous areas a size gradient is detectable; a less obvious gradient is indicated by catchment geology. The resulting "bottom up" stream types are compared to a recent stream typological system for Germany.

25 samples of two stream types, which were processed homogeneously in terms of sampling, sorting and identification served to compared the results of different resolutions. NMS and mean similarity analysis were performed to compare: (1) the complete taxa lists to only a subset of taxonomic groups, (2) abundance data to presence/absence data and (3) species level to family level resolution. Best discrimination of stream types resulted from complete taxa lists, abundance data and species level resolution.

Based on 67 summer samples, which were sampled in particular regions of Germany with a consistent method, ten stream types can be defined. Cluster analysis on the taxa lists helped to explain separations of stream type groups depicted in the NMS diagrams and abiotic differences visualised by overlays. Catchment size, altitude, geology and slope of the sampling sites formed major gradients.

Indicator value analysis (IndVal) was performed on 25 summer samples of mid-sized and large mountain streams to identify key indicator taxa for the two stream types. Species differed in their occurrence and abundance in the two stream types. A list on stream type specific species is presented.

1.1 Typology of streams in Germany sampled with various protocols

1.1.1 Introduction

The composition of stream biota depends on both, natural factors (e.g. stream size, altitude, catchment geology) and human pressures (e.g. alterations of water quality or hydromorphology). While the latter are recognised and classified with assessment systems, the natural differences are the basis for stream typologies. A stream typology classifies streams or stream reaches into entities with a limited variability of both, the invertebrate community composition and abiotic factors. Typologies came into the focus of hydrobiologists and water managers in the last decades and built the foundation of stream assessment systems all over the world (e.g. Clarke 1993; Omernik 1995; Verdonschot 1995; Wimmer et al. 2000). They can be organised "top down" by using geomorphological characteristics of river landscapes and the individual streams (Omernik 1995; Sommerhäuser 1998; Wimmer & Chovanec 2000; Schmedtje et al. 2001; Briem 2003), "bottom up" based on aquatic communities, or by a synthesis of both (Verdonschot 1995; Hawkins & Norris 2000; Moog et al. 2001).

As a framework for national top-down typologies the 25 European ecoregions defined by Illies (1978) are frequently used, particularly for applied purposes, like the implementation of the EU Water Framework Directive. In some cases they have been divided into sub-ecoregions (Moog et al. 2004) or "river landscape units" (Briem 2003).

In total Germany shares four of Illies' ecoregions (Figure 1): Central Lowlands (Ecoregion 14), Western Sub-alpine Mountains (Ecoregion 8), Central Sub-alpine Mountains (Ecoregion 9) and Alps (Ecoregion 4). However, for many water management purposes, such as assessment and restoration, more differentiated categories of streams are required or useful. In a first attempt to establish a more detailed stream typology for Germany, Schmedtje et al. (2001) suggested a top-down system, which is based on ecoregions, altitude, catchment geology, stream size and some additional parameters, such as the dominant substrate. This system was improved and refined by Sommerhäuser & Pottgiesser (2004; Appendix 1 and 2). It is based on expert judgement and defines 24 units of streams supposed to have different benthic invertebrate, macrophyte and phytobenthos communities. Although a bottom-up stream typology is always scientifically sounder, a national survey in Germany was not yet conducted. However, data availability and data quality increased recently, due to several national projects with particular focus on benthic invertebrates (Hering et al. 2004; Lorenz et al. 2004; Böhmer et al. in press; Lorenz et al. in press). A data source although still somewhat heterogeneous is now available, which enables an attempt of a bottom-up stream typology for Germany. Using this newly generated data set the following questions are addressed:

- Are ecoregional differences in benthic invertebrate communities detectable?
- Which longitudinal changes does the benthic invertebrate community reflect?
- Which other abiotic factors (e.g. altitude, catchment geology) are reflected by the invertebrate fauna?
- How many stream types, based on the benthic invertebrate fauna, can be distinguished in the mountainous areas of Germany?

1.1.2 Materials and methods

Data source and preparation

The data were acquired from various water authorities and research institutes all over Germany and compiled in an ACCESS-database. They originate from routine monitoring programs of the Federal States mainly following the sampling method described by DEV (1992) and from various scientific studies. For each sampling site abiotic parameters were collected (Table 1) and stored in the same database; the parameters were used as explanatory variables of the benthic community patterns.

Table 1. List of abiotic parameters compiled for each sample and used for explaining benthic community patterns. Provided by water authorities of the following Federal States: Bavaria, Brandenburg, Mecklenburg-Western Pomerania, Lower Saxony, North Rhine-Westphalia, Schleswig-Holstein and Thuringia.

Abiotic parameter	Classes	Data source
Ecoregion	4 (Alps), 8/9 (Western/Central Sub-alpine Mountains), 14 (Central Lowlands)	Illies (1978)
Catchment size [km²]	10 - < 100 (small); 100 - < 1000 (mid-sized); 1000 - < 10000 (large); ≥ 10000 (very large)	Data providers or GIS
Geology	Sandstone, schist, Pleistocene sediments, carbonate rocks/limestone	GIS: Stream landscapes of Germany (Briem 2003)
Altitude [m. a.s.l.]	< 100; 100 - < 200; 200 - < 500; 500 - < 800; ≥ 800	Topographical maps or data providers

Due to their different origin, the taxa lists were heterogeneous concerning the level of identification, sampling season, as well as sampling and sorting methods. They were thus processed and harmonised prior to analysis by applying presence/absence level and by restricting the analysis to six frequently sampled and well known taxonomic groups of benthic invertebrates: Mollusca, Ephemeroptera, Odonata, Plecoptera, Trichoptera and Coleoptera, which were identified in a comparatively consistent way and mainly to species level. Other abundant groups (e.g. Oligochaeta and Chironomidae) have been omitted due to the heterogeneous determination level. Representatives of certain taxonomic groups (e.g. Gammaridae) were evenly distributed in almost all samples and did, therefore, not add much explanatory power. These were excluded, too.

Data preparation was performed in three steps: (i) application of filter criteria, (ii) taxonomical adjustment, (iii) generation of regional and seasonal data subsets.

The data set was filtered by the criteria specified in Table 2 to restrict the data to samples of near-natural sites. This was necessary since the analysis aims at detecting differences based on natural parameters rather than degradation.

Taxonomical adjustment is a pre-requisite of all statistical analyses comparing taxa lists of different origin in order to delete errors based on heterogeneous data sets. Consistency in the taxa lists is derived by adjusting the taxa of a family to the lowest identified level of all samples. This was either species level if species identification was achieved in all samples or genus level if some lists only obtained genus level data.

Table 2. Criteria for data harmonisation and for restricting the data to near-natural streams.

Filter criterion	**Threshold value**	**Source**	**Reason, comment**
Criteria for excluding samples			
Catchment size [km²]	> 8	Data providers or GIS	Exclusion of crenal (spring/brook) sites
No. of genera	> 9	Taxa lists	Exclusion of taxon-poor (degraded) sites
German Saprobic Index (DEV 2003)	< 2.4	Taxa lists	Exclusion of polluted sites
Hydromorphological Index ("Gewässerstrukturgüte-kartierung") according to LAWA (2001)	< 4	Databases of regional water authorities	Exclusion of hydromorpho-logically degraded sites; exception: samples from large rivers (near-natural sites do not exist)
Land use	< 10 % residential area < 20 % cropland in the catchment	Corine Land Cover (Statistisches Bundesamt 1997)	Exclusion of sites with degraded catchments (Wang et al. 1997)
Criteria for including some questionable samples			
"Known reference sites/samples"	Not defined	Personal knowledge, published documentation	
Criteria for excluding taxa			
Frequency	< 3 samples	Taxa lists	Exclusion of rare taxa

The resulting data set, on which the analysis is based, comprises 390 benthic invertebrate samples of near-natural streams distributed all over Germany (Figure 1). Two sites are located in Poland near the Polish-German border. The majority of samples originate from Baden-Wuerttemberg (23.6 %), Lower Saxony (14.4 %), Bavaria (14.1 %) and North Rhine-Westphalia (13.6 %); the mountainous regions are better represented than the lowlands. Near-natural sites are usually lacking in areas with a high proportion of residential and/or agricultural land use (blank areas in Figure 1). This applies in particular to mid-sized and large streams. Furthermore, some areas are still not well investigated or data provision was not possible.

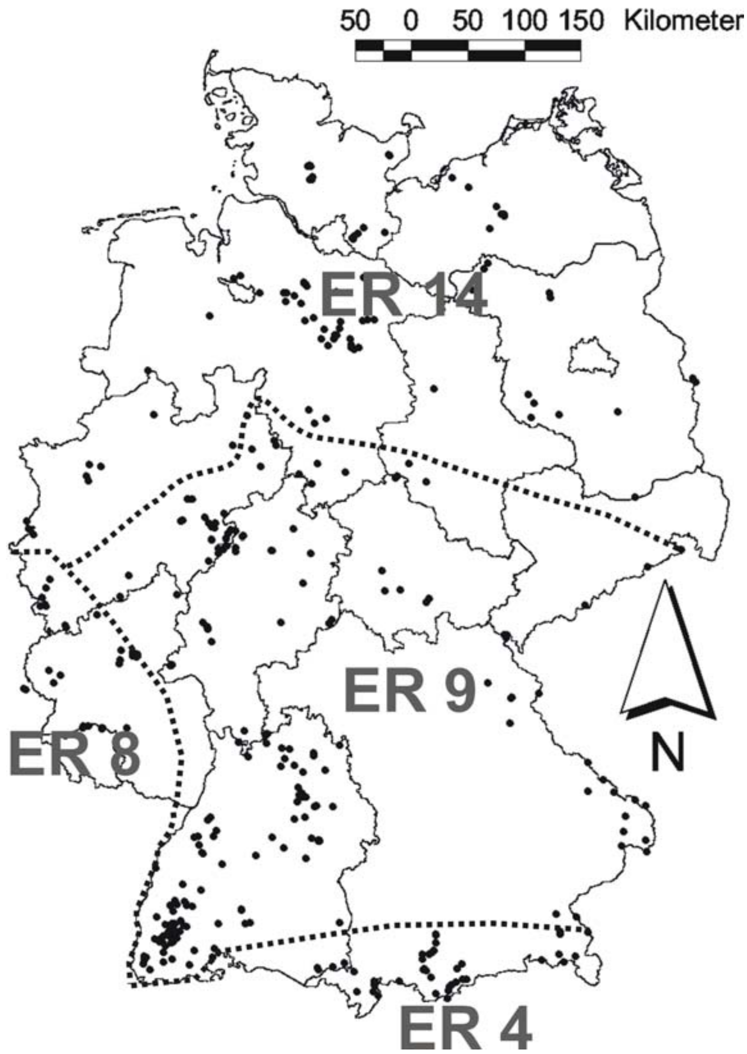


Figure 1. Map of Germany with the location of 390 sample sites within the different Federal States and the borderlines of the ecoregions. (ER 4 = Alps, ER 8 = Western Sub-alpine Mountains, ER 9 = Central Sub-alpine Mountains, ER 14 = Central Lowlands)

In the last step regional data subsets allowing for an analysis on different scales, and seasonal subsets reducing data variability between sample dates were generated. Regional data subsets were defined for:

(i) data from all of Germany
(ii) data from the ecoregions "Western Sub-alpine Mountains", "Central Sub-alpine Mountains" and "Alps"
(iii) data from the ecoregions "Western Sub-alpine Mountains" and "Central Sub-alpine Mountains".

Between-ecoregion analysis (data set (i)) was performed with presence/absence data on genus level, while within-ecoregion analysis (data sets (ii)-(iii)) with presence/absence data on species level.

For the seasonal subsets spring was defined from February to April and summer from May to August.

Statistical analysis

Non-metric Multidimensional Scaling (NMS) was used to detect and visualise differences in the benthic invertebrate communities (see Dufrêne & Legendre 1997 for background and advantages of NMS). NMS is based on a dissimilarity matrix using the Bray-Curtis dissimilarity index between each pair of samples, which is then entered into an iterative ordination procedure. The resulting multi-dimensional dissimilarity matrix is depicted in a low dimensional plot. The ordination plot displays the proportion of the faunal data variability explained by the ordination. Those two axes, which explain most of the variability, are displayed. The correspondence between the matrix and the final plot is explained by the "stress", which is zero in case of perfect concordance. Stress values below 0.05 (5 %) represent very good results, whereas values above 0.20 (20 %) are critical and values above 0.30 (30 %) indicate the ordination plot is not a meaningful representation of the samples (Clarke 1993). For interpretation purposes overlays were generated with the data specified in Table 1.

The software package PC-Ord 4.27 (McCune & Mefford 1999) was used, applying the autopilot method (slow and sorrow) and either the two- or three-dimensional solution. All analyses were performed separately for the spring and summer data sets. Due to different starting points for each ordination, all analyses were run several times to ensure stability of the results. To guarantee that differences are not the results of different investigators it was tested by generating overlays indicating the data source; no significant grouping due to the investigators was found.

1.1.3 Results

In an initial step the complete data set was analysed on genus level, resulting in a clear separation of streams in the Central Lowlands (ecoregion 14) from streams in the mountainous and alpine regions (ecoregions 4, 8 and 9), which showed no clear division (Figure 2).

Further on, data from ecoregion 14 were ignored. Data from ecoregions 4, 8 and 9 were jointly analysed.

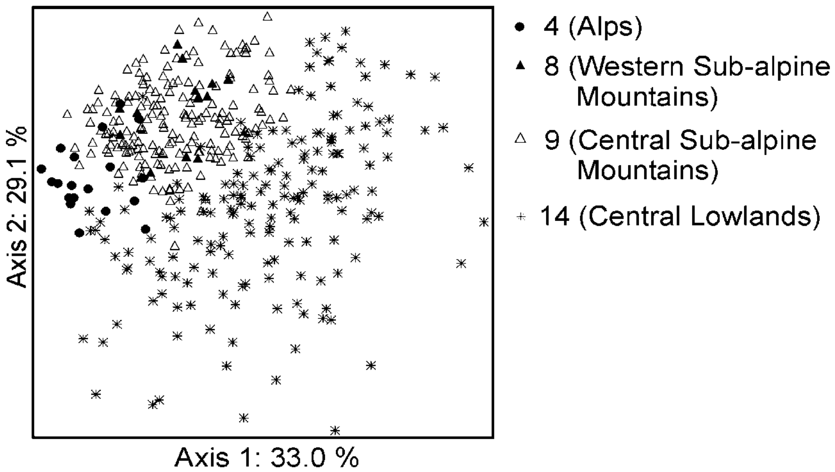


Figure 2. NMS ordination of benthic invertebrate samples (genus level) from lowland, mountain and alpine streams, classified by ecoregions; stress: 0.240.

Separate analyses were performed for spring (February to April) and summer (May to August) samples: In total 78 samples with 139 taxa were used for the spring analysis and 116 samples with 165 taxa for the summer analysis.

In two initial steps two clearly separated stream types were identified:

- streams in alpine regions (ecoregion 4) can easily be distinguished from the streams of ecoregion 8 and 9 (the respective diagram for the spring data is given in Figure 3).
- large rivers (for which only summer data are available) form a clearly separated group (Figure 4).

These samples and a few outliers were omitted in further analysis.

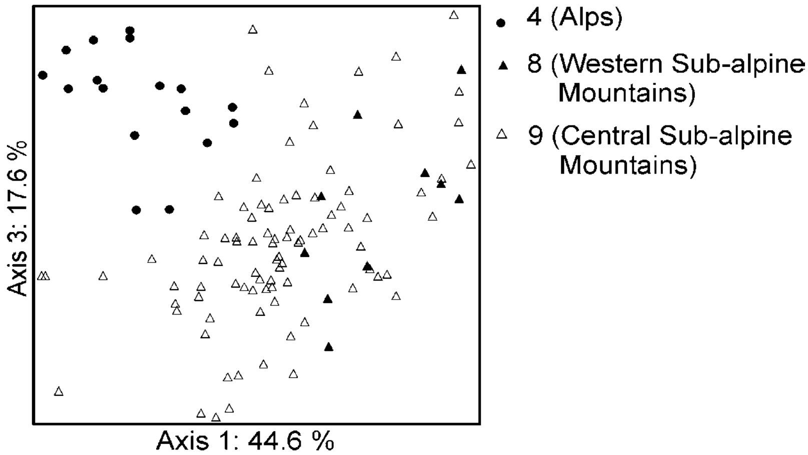


Figure 3. NMS ordination of benthic invertebrate samples (species level; spring data) from mountain and alpine streams classified by ecoregion; 115 samples and 166 taxa; stress: 0.189.

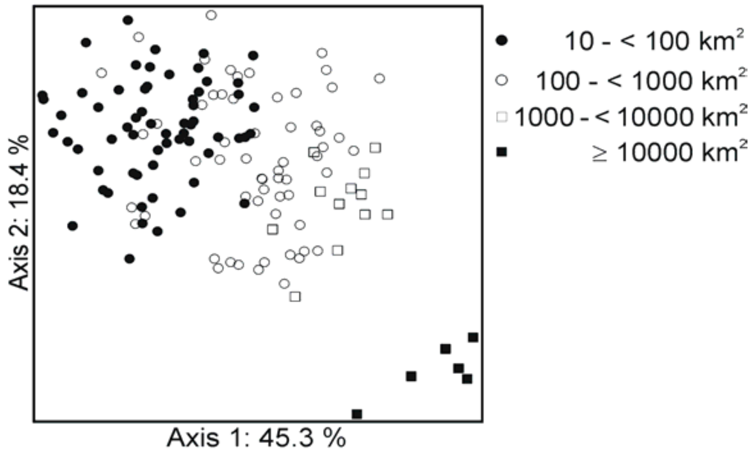


Figure 4. NMS ordination of benthic invertebrate samples (species level; summer data) from mountain streams classified by catchment size; 139 samples and 181 taxa; stress: 0.191.

For each season figures were produced with two overlays: (1) size classes of the catchment (Figure 5 A and B), (2) geology of the catchment (Figure 6 A and B).

Catchment size gradients are obvious determinants of the mountain stream communities: for the spring data, the size gradient is parallel to axis 1 (Figure 5 A), for the summer data parallel to axis 3 (Figure 5 B). In each season they account for approximately 40 % of the variance in the data. In both seasons, there is a clear grouping of small (< 100 km^2 catchment size) and large streams (> 100 km^2). Within the latter group, large streams (≥ 1000 km^2 catchment size, present only in the summer data set) cannot be distinguished from mid-sized streams (100 – 1000 km^2 catchment size).

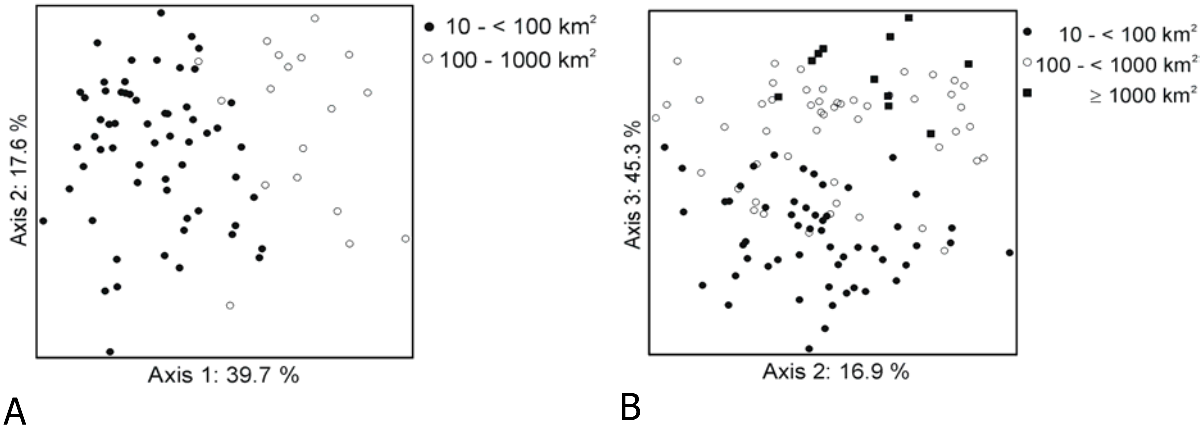


Figure 5. NMS ordination of benthic invertebrate samples (species level) from mountain streams classified by catchment size. A) Spring data with 78 samples and 139 taxa; stress: 0.190. B) Summer data with 116 samples and 165 taxa; stress: 0.196.

Figure 6 displays the geology of the sampling sites. For the summer data a clear separation of groups is not possible, mainly due to a superimposing effect of the factor catchment size (Figure 6 B). However, for the spring samples small siliceous schist streams are predominantly located in the upper left part of the diagram, siliceous sandstone streams in the lower left part, carbonate rock (limestone, marl or Pleistocene sediments) streams in the centre and large siliceous streams on the right side (Figure 6 A).

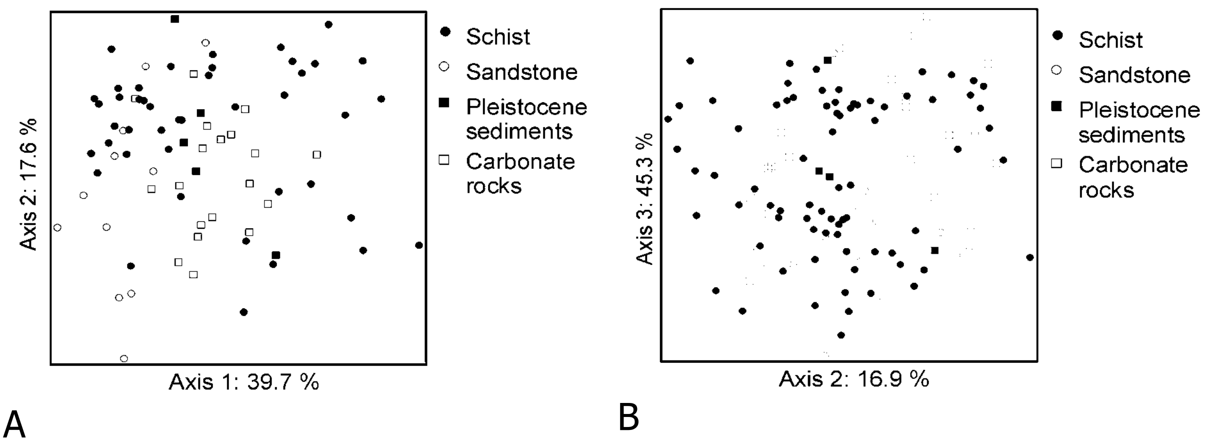


Figure 6. NMS ordination of benthic invertebrate samples (species level) from mountain streams classified by catchment geology. A) Spring data with 78 samples and 139 taxa; stress: 0.190. B) Summer data with 116 samples and 165 taxa; stress: 0.196.

1.1.4 Discussion

Like in other countries (e.g. Feminella 2000; Gerritsen et al. 2000; Sandin & Johnson 2000), ecoregion is the underlying parameter for distinguishing the benthic invertebrate community of German streams. Thus, the faunal composition is mainly determined by abiotic factors like altitude, hydrology, temperature, slope and substrate composition. A community-based separation of the lowland, lower mountainous and the alpine areas is obvious, however a separation of the two lower mountainous ecoregions 8 and 9 (Western and Central Sub-alpine Mountains) is not possible, likely due to the similarity of abiotic factors in these regions. The importance of ecoregions was also observed by Moog et al. (2004) in Austria, where ecoregions and subecoregions explain most of the benthic invertebrate variability. In other parts of the world, e.g. in the Mid-Atlantic Highlands, USA, the ecoregional approach alone is not satisfying (Waite et al. 2000). Other factors must be taken into consideration in addition to ecoregions to explain the composition of the stream fauna. According to Rundle et al. (1993) and Brewin et al. (1995) catchment area is the second important factor in separating stream assemblages; only altitude is more important. Classifications based on (1) ecotones (size, substrate type, channel type) and (2) higher landscape scales were preferred in the review by Hawkins et al. (2000).

Also in this analysis, other parameters complement ecoregions. Both seasonal subsets revealed a size gradient in the lower mountainous regions (Figure 5), which is well known from basic concepts for the longitudinal zonation of streams (e.g. Illies 1961; Vannote et al. 1980). This prevailing "typologically relevant" parameter can be expressed as catchment size or distance to source. However, not all samples fit perfectly into this gradient. This might partly be due to the size class boundaries applied (10, 100, 1000 and 10000 km²), which were taken from the Water Framework Directive providing an artificial classification.
Small streams with catchment sizes below 100 km^2 have a different faunal composition than streams with larger catchments. The second parameter determining the fauna is the geology of the catchment area. In particular, Central European carbonate streams are inhabited, amongst other, by invertebrate taxa like *Rhyacophila pubescens*, *Synagapetus dubitans*, *Tinodes dives*, *Tinodes unicolor* (Trichoptera) or *Riolus* sp. (Coleoptera) (Braukmann 1987; Haase 1998), which lead to a weak but visible separation of carbonate streams in my analysis. Due to pre-summer emergence many of these differentiating species are no longer present in the summer analysis and thus, the ability to distinguish samples by catchment geology failed.

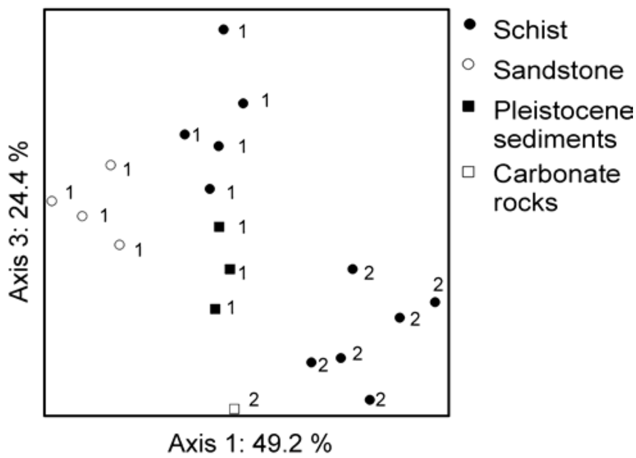


Figure 7. NMS ordination of benthic invertebrate samples (species level) from mountain streams classified by catchment geology and numbered by catchment size (1 = < 100 km^2, 2 = 100 - 1000 km^2). Spring data with 19 samples and 98 taxa; stress: 0.081.

The more pronounced separation of sandstone streams is probably due to the fine geological material, which leads to the presence of gravel and sand patches and, thus, a higher substrate diversity than is normally found in schist or carbonate streams. Separation by catchment geology is less obvious than separation by stream size, although many parameters are dependent on catchment geology and differ extremely: the channel morphology, the size and form of the channel substrate, and chemical parameters such as conductivity and total hardness. In accordance to this, Heino et al. (2003) analysed 235 boreal headwater streams (catchment sizes 1 - 60 km^2) in Finland and were able to separate only two discrete stream types, with latitude as the predominant descriptor and besides several factors (pH, water depth, shading) with large gradients between the sampling sites.

Streams in the German Alps are characterised by altitudes > 800 m above sea level, a braided channel form, fist-sized round pebbles and alpine discharge patterns with steep summer hydrographs. Their benthic invertebrate communities can be distinguished from the mountain streams by species adapted to these conditions, such as several stoneflies (e.g. genus *Rhabdiopteryx*), mayflies (e.g. *Rhithrogena alpestris*) and caddisflies (e.g. *Rhyacophila torrentium*, *R. vulgaris*). Within the alpine region differences in catchment size is not that relevant for community composition, because the alpine character in terms of hydromorphology, temperature and hydrology superimposes the effects of catchment size. Similar observations have been made in Austria, a country mainly covered by the Alps, where ecoregions and subecoregions explain the faunal variability best, and catchment size is of minor importance (Moog et al. 2004).

Table 3. Potential stream types for Germany. (Ecoregions: 4 = Alps, 8/9 = Western/Central Sub-alpine Mountains)

Stream group	Ecoregion	Catchment size [km^2]	Substrate	Geology
A	4	10 – 500	Gravel/pebbles	Carbonate
B	8/9	10 – 100	Pebbles/cobbles	Siliceous/carbonate
C	8/9	100 – 10000	Pebbles/cobbles	Siliceous/carbonate
D	8/9	> 10000	Gravel	Siliceous/carbonate

1.1.5 Conclusion

Despite the comparatively small number of near-natural sites, for which data are available and besides the heterogeneity of the data several groups of stream macroinvertebrate communities can be clearly distinguished. Likely, more homogeneous data gathered using a standardised sampling and sorting protocol (compare Haase et al. in press) would lead to a clearer and further sub-division of stream types, which is also indicated by metrics, such as feeding type composition or habitat preferences (Hering et al. in press). The lack of real reference sites in some parts of Germany and in particular in large rivers is another limiting factor. However, based on the data set used the benthic invertebrate communities of four "stream groups" can be clearly separated (Table 3), some of which can be subdivided further. In contrast, the recent German "top-down" typology (Sommerhäuser & Pottgiesser 2004; Appendix 1 and 2) outlines 24 stream types for the entire country and 12 for the mountain and alpine regions. In the following, focussing on the mountain and alpine regions these two approaches are compared.

- Group A comprises alpine streams, clearly separated by the benthic invertebrate community as well as by abiotic features (coherent to Type 1 as defined by Sommerhäuser & Pottgiesser 2004).
- Group B covers small streams in lower mountainous areas. It can be subdivided into three units according to the catchment geology: Siliceous (schist) streams (Type 5), siliceous sandstone streams (Type 5.1) and carbonate streams (Types 6 and 7). Analysing a small number of samples taken with a harmonised method, clear separations between streams in different geological formations have been found (Figure 7).
- Group C comprises mid-sized streams in the lower mountainous areas (Types 9, 9.1 and 9.2).
- Group D (large rivers in mountainous areas) is clearly separated and coherent to Type 10.

1.2 Comparison of NMS resolution for taxonomic levels and quantitative differences between two stream types

1.2.1 Introduction

Typological analyses are often tainted with the flaw of subjective decisions of the authors. Taxonomic resolution and the choice of a quantity level are subjects of discussion and can lead to completely different results. Beside the heterogeneity of data, the subjectivity of the analysts often results in certain directions. Family level identification is favoured by some authors (e.g. Feminella 2000) but many more appreciate species level (e.g. Hawkins & Vinson 2000; Waite et al. 2000). The same bidirectionality can be seen in the question, if presence/absence or abundance data should be used, which is synonymous with the downweighting of abundant species and the increase of the importance of rare species (Cao et al. 2001). To find out, which taxonomic resolution and abundance data are necessary and if the results are different, samples taken in two stream types in summer were analysed.

The data set was homogeneous in terms of season, sampling, sorting and identification. NMS multivariate analysis and cluster analysis were performed to clarify the grouping of samples according to the chosen resolution.

Statistical tests for multivariate analysis to overcome problems of taxonomic resolution and quantity differences are scarce. However, Van Sickle (1997) developed a program to test the (dis)similarity of predefined groups in data sets. Differences and similarities in the results aim at a proposal for further typological studies by answering the following questions:

- Is a separation of the mid-sized and large streams (respectively stream types 9 and 9.2 according to Sommerhäuser & Pottgiesser 2004) possible on different taxonomic levels (species, family)?
- Are the results different if the complete faunal community is considered instead of only the taxonomic groups Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Odonata and Mollusca (EPTCOM)?
- Are the results different if log-transformed abundance data are used instead of presence/absence data?

1.2.2 Materials and methods

Database

In total 25 summer samples from mid-sized and large mountain streams (stream types 9 and 9.2 according to Sommerhäuser & Pottgisser 2004; Table 5) of the AQEM-project and a LAWA-project (compare Definitions – Abbreviations) were used. All sites are in a moderate, good or high ecological status according to the new assessment system for Germany (AQEM-software; compare Definitions – Abbreviations). A multi-habitat-sampling protocol (Hering et al. 2004) was applied for the following samples: 12 samples (mid-sized streams) derived from the summer sampling in the AQEM-project (summer 2000), 13 samples (large streams) were taken by colleagues of the Research Institute Senckenberg and by me in a joined LAWA-project (compare Definitions – Abbreviations) in summer 2003.

All organisms were identified to the lowest possible level, which was mainly species or genus level (Table 4). Oligochaeta and individuals of some Diptera-families were identified on family level.

Table 4. Identification level of the macroinvertebrate samples.

Taxonomic group	Identification level
Turbellaria	Species
Gastropoda	Species
Bivalvia	Species
Oligochaeta	Family
Hirudinea	Species
Crustacea	Species
Ephemeroptera	Species
Plecoptera	Species/Genus
Odonata	Species
Heteroptera	Species/Genus
Coleoptera	Species
Planipennia	Species
Megaloptera	Species
Trichoptera	Species
Tipulidae/Limoniidae	Genus
Psychodidae	Genus
Simuliidae	Species/Genus
Chironomidae	Subfamily
other Nematocera	Family
Brachycera	Family

Table 5. Characteristics of the sampling sites used in the taxonomic resolution analysis; the site code will be used as an abbreviation in Appendix 7 and Appendix 8. (Federal State: BW = Baden-Wuerttemberg, HE = Hesse, NW = North Rhine-Westphalia, RP = Rhineland-Palatinate; stream type number according to Sommerhäuser & Pottgiesser (2004; Appendix 1))

Site code	Stream name	Site name	Federal State	Sampling date	Easting	Northing	Stream system	Altitude [m]	Catchment area [km²]	Stream type
D0500012	Rur	Dedenborn	NW	26.06.2000	2524435	5604443	Maas, Rhine	315	185	9
D0500022	Rur	Wiselsley	NW	26.06.2000	2520212	5602726	Maas, Rhine	360	154	9
D0500042	Kyll	Densborn	RP	19.07.2000	2542953	5553280	Moselle, Rhine	305	472	9
D0500052	Kyll	Erdorf	RP	20.07.2000	2540643	5541632	Moselle, Rhine	245	572	9
D0500072	Our	Auel	RP	20.07.2000	2512527	5564621	Moselle, Rhine	360	294	9
D0500082	Nims	Birtlingen	RP	20.07.2000	2534774	5534570	Moselle, Rhine	245	222	9
D0500092	Ahr	Altenahr	NW	19.07.2000	2570641	5597244	Rhine	156	750	9
D0500142	Nuhne	Neukirchen	HE	29.06.2000	3481527	5665196	Eder, Weser	310	134	9
D0500152	Eder	Röddenau	HE	30.06.2000	3481725	5655122	Weser	280	524	9
D0500172	Orke	Dalwigksthal	HE	29.06.2000	3487426	5668330	Eder, Weser	295	275	9
D0500182	Orke	Reckenberg	HE	29.06.2000	3488457	5668668	Eder, Weser	280	289	9
D0500202	Prüm	Wüstung Beifels	RP	20.07.2000	2530316	5545925	Moselle, Rhine	280	327	9
D1000012	Fulda	Richthof	HE	10.06.2003	3541196	5626306	Weser	217	1214	9.2
D1000022	Fulda	Kerspenhausen	HE	10.06.2003	3545992	5631034	Weser	205	1488	9.2
D1000032	Sieg	Buisdorf	NW	18.06.2003	2586241	5628142	Rhine	56	1905	9.2
D1000062	Eder	Niedermöllrich	HE	08.07.2003	3524727	5664456	Weser	162	1781	9.2
D1000072	Diemel	Deisel	HE	08.07.2003	3529372	5717694	Weser	114	1603	9.2
D1000082	Lahn	Bellnhausen	HE	14.07.2003	3479982	5618890	Rhine	165	1848	9.2
D1000092	Kyll	Ehrang	RP	27.06.2003	2549540	5519085	Rhine	130	844	9.2
D1000102	Fränkische Saale	Gemünden	HE	17.06.2003	3551220	5549000	Weser	160	2184	9.2
D1000112	Jagst	Widdern	BW	22.06.2003	4312680	5467610	Rhine	191	1233	9.2
D1000122	Leine	Betheln (Elze)	HE	21.06.2003	3552300	5776000	Weser	75	2229	9.2
D1000132	Nahe	Monzingen	HE	18.06.2003	3398380	5518290	Rhine	157	1469	9.2
D1000152	Werra	Wasungen	HE	19.06.2003	4385500	5615500	Weser	267	1342	9.2
D1000162	Fulda	Richthof	HE	10.06.2003	3541150	5626100	Weser	217	1214	9.2

Statistical analysis

The taxa lists were adjusted to different taxonomic levels and processed in the following way:

(i) For family level all organisms of each family were summed up, except for Oligochaeta (order level) and Turbellaria (class level).
(ii) For species level all organisms were adjusted to the lowest overall level.
(iii) In terms of the quantity differences the abundance data were either log (x+1) transformed;
(iv) or changed into presence (1) / absence (0).
(v) If the analysis was restricted to Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Odonata and Mollusca (EPTCOM) the other taxonomic groups were ignored.

These criteria resulted in the following files:

(i) 25 samples with 68 families for the family level analysis of the complete taxa lists
(ii) 25 samples with 40 families for the family level analysis of the taxonomic groups EPTCOM
(iii) 25 samples with 173 species for the species level analysis of the complete taxa lists
(iv) 25 samples with 90 species for the species level analysis of the taxonomic groups EPTCOM
(v) the files (i) to (iv) both with log (x+1) transformed abundances and presence/absence

NMS (see Chapter 1.1.2) was performed on the processed taxa lists and only the two strongest axes are displayed in the results. To classify the samples a cluster analysis was carried out using Soerensen Index as distance measure and Flexible Beta as linkage method. Wards method is said to be the most reliable (recommended) and best applicable for ecological questions (Cao et al. 1997; McCune & Mefford 1999), but Wards method is incompatible with Soerensen Index (McCune & Mefford 1999). Sneath and Sokal (1973) suggested that a Beta value of – 0.25 for the Flexible Beta linkage method make it behave similar to Wards method. The results of the cluster analysis were used as overlays for the NMS plots.

The NMS and the cluster analysis were conducted with the program PC-Ord 4.27 (McCune & Mefford 1999).

Mean (dis)similarity

The exact separation of cluster groups is difficult to display in an ordination plot, because the downgrading of a multidimensional analysis to a two-dimensional diagram leaves some variance undisplayed. Mean (dis)similarity dendrograms summarise the information contained in a complex ordination and present it in a simpler form (Van Sickle 1997).

Bray-Curtis similarity measure was used to calculate the percentage of similarity for the sites within each cluster group (W_i for the individual groups, W~ for overall mean within-group similarity) and between two different cluster groups (B~). Values (W_i, W~ and B~) are measured in similarity units and can range from 0 (no similarity) to 1 (complete similarity). They can be presented as 0 to 100 %. Additionally the classification strength (CS) is achieved by B~ – W~ as an overall measure to compare the performance of alternative classifications.

To test for multivariate differences among predefined groups (McCune & Grace 2002), the inner- and between-group (dis)similarity was calculated from the results of the Multi-Response Permutation Procedures (MRPP) of the NMS plots in family and species level analysis (Table 6). The MRPP was performed with the software package PC-Ord 4.27 (McCune & Mefford 1999). As a result the mean within-group dissimilarity for each group (W_i), the overall mean of all dissimilarities ("Expected Delta") and the weighted overall mean (W~) of the within-group dissimilarities (W~; "Observed Delta") is given. They are transfomed by a simple subtraction (1 – x) to similarities. B~ (the between-group similarity) is the only information not supplied by MRPP. To calculate B~ the program MEANSIM6 of Van Sickle (1997) was used, which is downloadable from the website of the US environmental protection agency (http://www.epa.gov/wed).

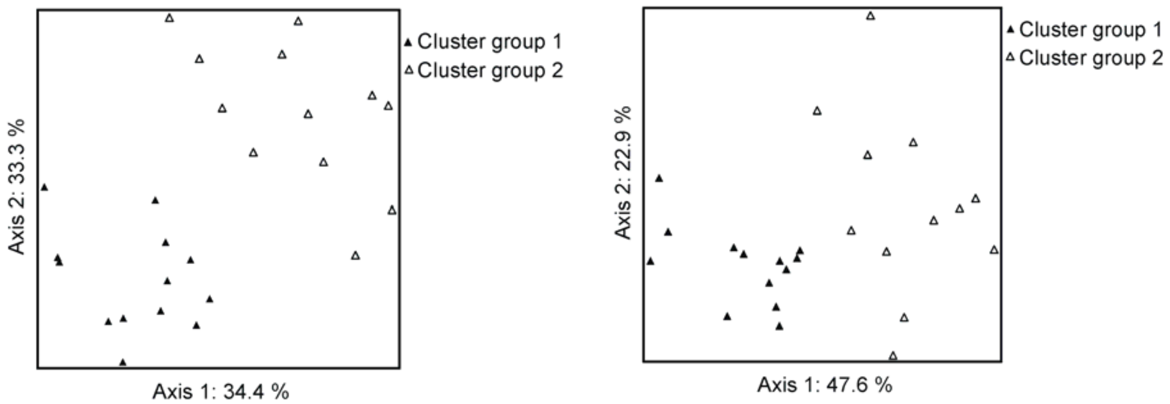
In the mean similarity dendrograms (e.g. Figure 12) the mean similarity values show the degree, to which objects within the same group are more similar to each other than they are to objects in the other group. The mean between-group similarity is plotted as a vertical line with branches (horizontal lines), which represent the within-group similarities (Figure 12). In strong classifications B~ is small (the vertical branch is at the lower end of the similarity) and each W_i is large (large horizontal branches), indicating a high degree of discrimination between groups.

A permutation test (Van Sickle & Hughes 2000) was used to evaluate the significance of the classification.

1.2.3 Results

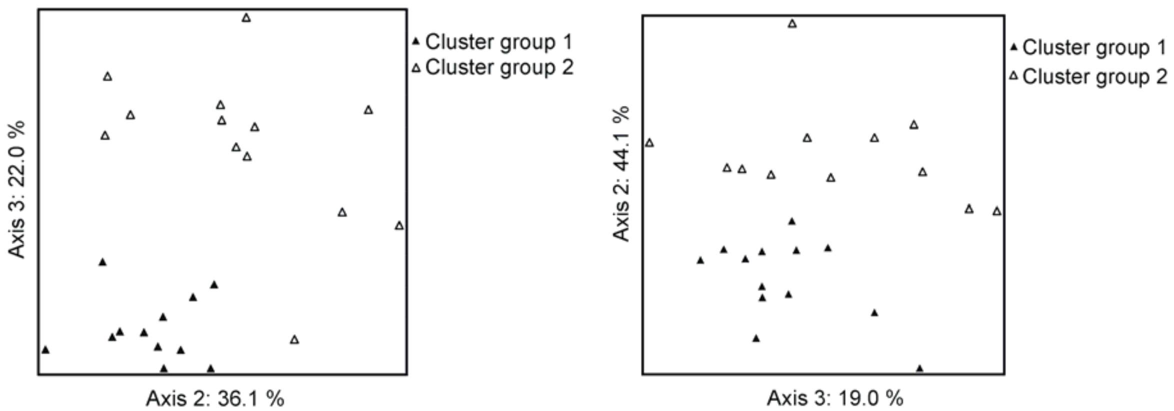
Results of the analysis on family level

In the family level analysis all plots (Figure 8 and Figure 9) display low stress (below 0.15) and high explanatory power for the two strongest axes (together above 60 %). The sites are ordered into two cluster groups reproducing the predefined stream types, except for the site Eder at Niedermöllrich. This site is always clustered together with the mid-sized streams although the catchment is larger than 1000 km^2. If only the groups EPTCOM and the log-transformed abundances are taken into account, then one of the mid-sized streams is clustered together with the large streams. In the visual presentation though, this site joins the other stream type 9 sites more than the stream type 9.2 sites (Figure 9).



A B

Figure 8. NMS ordination of 25 benthic invertebrate samples on family level considering the complete taxa lists; A) abundance data log (x+1) transformed; stress: 0.116. B) presence/absence; stress: 0.128. Cluster group 1 contains all mid-sized streams and one large stream (Eder Niedermöllrich), cluster group 2 contains solely large streams.

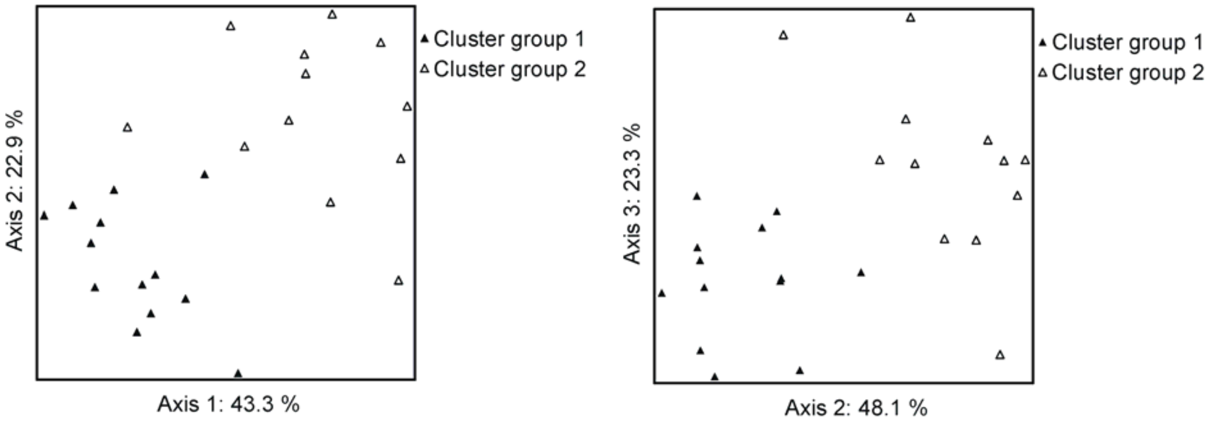


A B

Figure 9. NMS ordination of 25 benthic invertebrate samples on family level considering the taxonomic groups EPTCOM; A) abundance data log (x+1) transformed; stress: 0.120; cluster group 1 contains mid-sized streams and one large stream (Eder Niedermöllrich), cluster group 2 contains large streams and one mid-sized stream (lower right side). B) presence/absence; stress: 0.142; cluster group 1 contains all mid-sized streams and one large stream (Eder Niedermöllrich), cluster group 2 contains solely large streams.

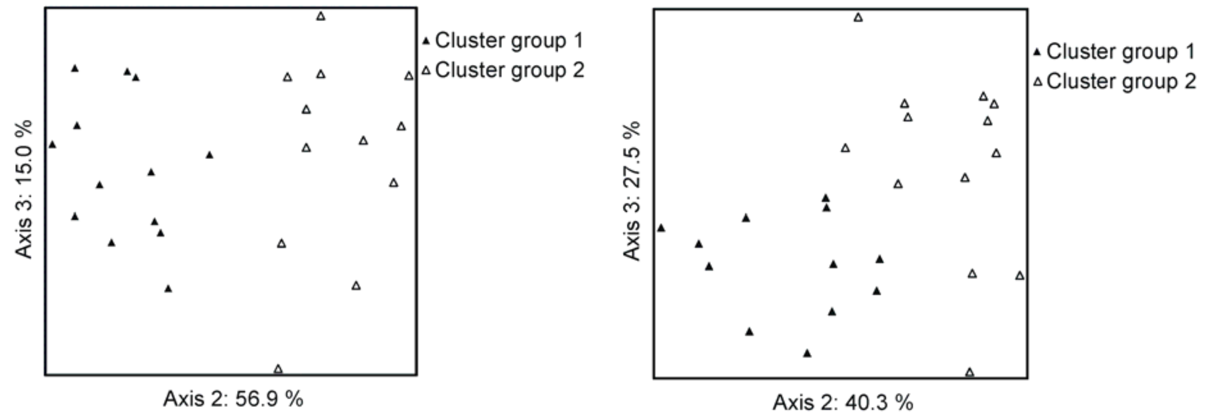
Results of the analysis on species level

Analogous to the family level analysis all plots (Figure 10 and Figure 11) for the species level analysis show low stress (below 0.15) and high explanatory power for the axes (above 60 %). The two stream types are well partitioned and look alike in all 4 figures. All clusters place the site Eder at Niedermöllrich to the stream type 9 group (mid-sized streams), except for the analysis of the taxonomic groups EPTCOM and presence/absence level.



A B

Figure 10. NMS ordination of 25 benthic invertebrate samples on species level considering the complete taxa lists; A) abundance data log (x+1) transformed; stress: 0.113. B) presence/absence; stress: 0.125. Cluster group 1 contains all mid-sized streams and one large stream (Eder Niedermöllrich), cluster group 2 contains solely large streams in both stream figures.



A B

Figure 11. NMS ordination of 25 benthic invertebrate samples on species level considering the taxonomic groups EPTCOM; A) abundance data log (x+1) transformed; stress: 0.114; cluster group 1 contains all mid-sized streams and one large stream (Eder Niedermöllrich; in the middle), cluster group 2 contains solely large streams; B) presence/absence; stress: 0.148; cluster group 1 contains all mid-sized streams, cluster group 2 contains solely large streams.

Results of the mean similarity analysis

The within-group similarities (W_i) on family level range on a high level between 66 and 80 % (Table 6). In contrast to that W_i´s for species level show between 53 and 61 % similarity. The mentioned groups (W_i group 1 and 2) are the cluster groups of the NMS plots in Figures 8 - 11. The between-groups similarity is also higher on family level than on species level (> 60 % against < 51 %). Another aspect poses the within-similarity, which is always higher in group 1 streams (stream type 9) than in the group 2 streams. This can be seen in the figures (e.g. Figure 11), where the group 1 streams form a more compact group.

The similarity resolution of the different taxonomic and abundance levels is indicated by the B~ column. The lowest B~ (between-group similarity) value is calculated for species level and abundance data, both, for EPTCOM and complete taxa list (45 %). This indicates a strong partitioning of the groups in comparison to the family level, EPTCOM and presence/absence data (69 %), which displays a much higher similarity among groups. Furthermore, there is a subtle difference in the classification strength (CS) between family and species level resolution. The highest CS-values are calculated for species level, complete taxa lists and both quantity levels (above 10 %); lowest can be found for family level EPTCOM and again both quantity levels (below 8 %).

Each classification shows statistical evidence with a significance level of $p < 0.001$.

Table 6. Strengths of the two NMS stream type groups. Within- (W_i for individual groups) and between- (B~) group similarity, observed (W~ for both groups) and expected delta, the classification strength (CS; a measure of overall classification success) and p of the tested taxonomic levels and quantity measures.

Resolution	W_i group 1	W_i group 2	Observed Delta (= W~ for both)	Expected delta	B~	CS = W~ − B~	p
Family level, complete taxa lists, abundance	0.72	0.66	0.69	0.65	0.61	0.085	<0.001
Family level, complete taxa lists, presence/absence	0.78	0.71	0.74	0.70	0.65	0.089	<0.001
Family level, EPTCOM, abundance	0.73	0.66	0.69	0.66	0.62	0.074	<0.001
Family level, EPTCOM, presence/absence	0.80	0.72	0.76	0.72	0.69	0.075	<0.001
Species level, complete taxa lists, abundance	0.58	0.53	0.56	0.50	0.45	0.106	<0.001
Species level, complete taxa lists, presence/absence	0.61	0.58	0.60	0.54	0.49	0.109	<0.001
Species level, EPTCOM, abundance	0.57	0.53	0.55	0.50	0.45	0.099	<0.001
Species level, EPTCOM, presence/absence	0.61	0.58	0.59	0.54	0.50	0.088	<0.001

The mean similarity dendrograms (Figure 12) depict the results of the mean similarity analysis. Abundance data have always a consistently lower between-group similarity than presence/absence data. The branches (within-group similarity) are equal long for group 1 in family and species level resolution but show higher within-group similarity for group 2 in species level than in family level.

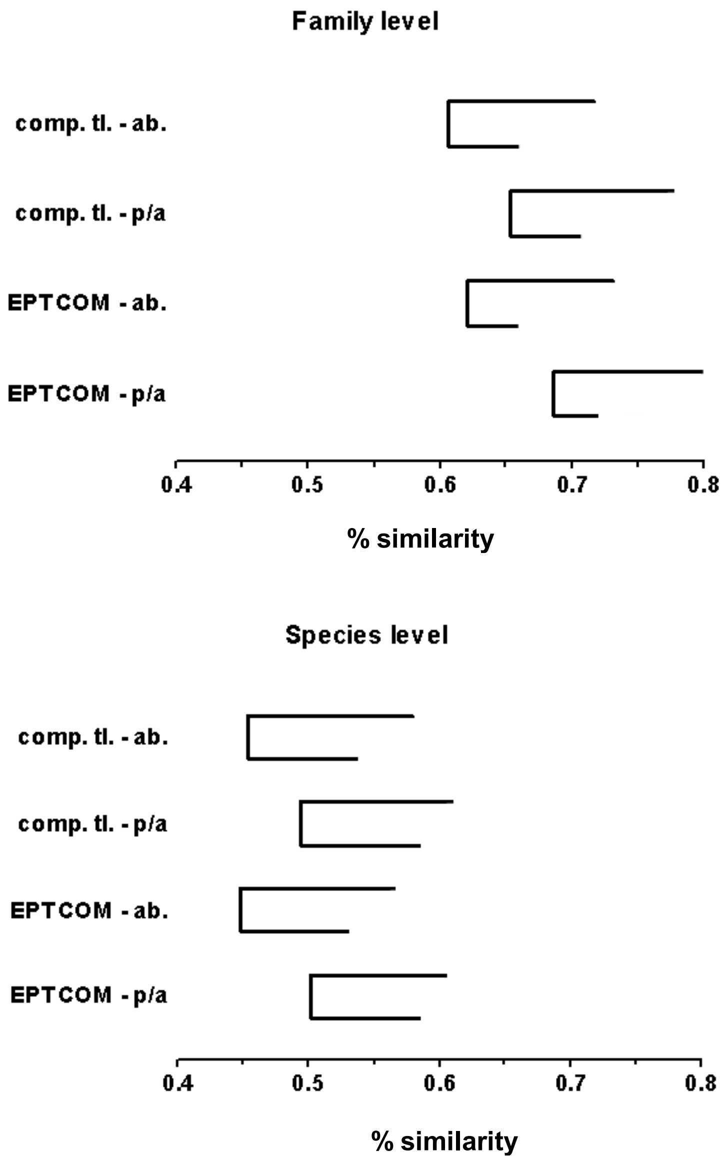


Figure 12. Mean similarity dendrograms of family and species level identification for taxa lists and quantity differences. Vertical lines = mean between-group similarity (B~); horizontal branches = mean within-group similarity (W_i). Upper branches represent % similarity of group 1; lower branch represent % similarity of group 2; horizontal branches to the right represent an increase in similarity in that group. (comp. tl. = complete taxa list; ab. = abundance; p/a = presence/absence)

1.2.4 Discussion

The samples representing the top-down defined stream types are well separated in all NMS plots. Thus, the identification of two stream types is visible on every taxonomic and quantity level. The cluster analysis distinguishes between the stream types, too.

The predefined type 9.2 site Eder at Niedermöllrich is the only exception. It is clustered to the stream type 9 (except for EPTCOM and presence/absence) although the catchment area is larger than 1000 km^2. This stream has a faunal assemblage of mid-sized streams, probably caused by a deep-water outflow of a reservoir in the main channel a few kilometres upstream of the sampling site. This outflow has a low water temperature and thus, support more cold stenothermic species, which are normally present in smaller streams.

Differences between the taxonomic and quantity resolutions are obvious in the dissimilarity table (Table 6) and to a smaller degree in the stress of the NMS plots. The stress is always a little bit higher if the taxonomic groups EPTCOM and presence/absence data are used and not the complete biocoenosis and abundance data. This is an indication that the discrimination between stream types is better if the complete faunal community and abundance data are used in the analysis.

The mean between-groups similarity is higher in the family level taxonomic resolution compared to the species level resolution (Table 6), which is due to the fact, that many macroinvertebrate families inhabit both stream types. Families, found in only one of the two stream types form a minority. However, if species level is applied the similarity between the stream types is consistently lower, because different species of the same family inhabit the two stream types. Van Sickle & Hughes (2000) and Waite et al. (2000) observed the same pattern of higher between-group similarity for family level. In relation to each B~, the within-group similarities are nearly equal for the different taxonomic and abundance levels (W~ for the two groups). Thus, the within-group similarity did not change with the taxonomic level but the between-group similarity.

The classification strength (CS = W~ – B~) has highest scores for species level, complete taxa list and for both quantity levels. Although the values are not high (< 11 %) all CS-values are significant, which is supported by similar results obtained by Waite et al. (2000; "CS generally weak"), Gerritsen et al. (2000; CS < 14 %) and Van Sickle & Hughes (2000; CS range: 7 - 13 %). Furthermore, Waite et al. (2000) found clearer pattern of sites in the ordination space if species level was adopted.

However, often heterogeneity of data does not allow for this "perfect" solution (see Chapter 1.1). On the other hand, the results of other more summarising resolutions lead to comparable conclusions. The cluster analysis showed the same results and B~ is nearly as high. If only EPTCOM and presence/absence data are encountered, the results are also clear and can be used for typological questions but the separation of groups is not so evident. Cao et al. (2001) concluded by reviewing several papers that results based on single taxonomic groups were similar to analyses based on all taxonomic groups.

For typological questions, it can be concluded that species level identification of the complete taxa list and log-transformed abundances discriminate best between faunal assemblages of different stream types.

Family level compared to species level resolution results in approximately 20 % more between-groups similarity (thus, 20 % less discrimination) in all four variations of calculation and therefore, should not be preferred.

1.3 Typology of streams in Germany sampled with a consistent method

1.3.1 Introduction

The main criticism on the validation of the German stream typology (Chapter 1.1; Lorenz et al. in press), refers to the low number of taxonomic groups taken into account (Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Odonata and Mollusca) and the use of presence/absence information. However, the heterogeneity of the data did not allow for a better resolution. This heterogeneity is mainly due to the fact that the various water authorities, universities and other organisations who delivered the data used different abundance classes or only presence/absence level, sampled with diverse methods, using mesh sizes ranging from 100 to 2000 μm and different sorting procedures such as life-, field- or lab-sorting with various restrictions (time, abundance, number of taxa). Consequently, the smallest common denominator was the reduction of the data to the taxonomic groups EPTCOM and to presence/absence level.

With the implementation of the AQEM-method (Hering et al. 2004), several projects in the last two years have collected data with the same method, greatly increasing the database of comparable samples. The Research Institute Senckenberg and the University of Duisburg-Essen sampled in several regions of Germany consistently applying the AQEM-method. Besides, highly skilled workers raised the level of identification to species level in nearly all taxonomic groups. Furthermore, during these research projects many near-natural sites were sampled and with the collected data, it is expected to get a more indepth insight into (macroinvertebrate) stream typology. The regions sampled are small and do not cover all *a priori* German stream types (predefined by Sommerhäuser & Pottgiesser 2004). But the consistency of the data makes it ideal for a detailed analysis.

As a consequence of Chapter 1.2.4 (taxonomic resolution), data on the complete faunal community with log (x+1) transformed abundances are used. Achieving the best discrimination possible between stream type groups, the following questions are addressed:

- Is the separation of stream types possible in the data set?
- Can the stream types of Chapter 1.1 (compare also Lorenz et al. in press) be validated with the new data set?
- Are more stream types distinguishable than in Chapter 1.1 (compare also Lorenz et al. in press)?

1.3.2 Materials and methods

Database

67 samples of near-natural streams formed the database of this analysis (Table 7). All samples were taken by ecologists of the University of Duisburg-Essen or the Research Institute Senckenberg, consistently applying the AQEM-method (Hering et al. 2004). Summer samples of four different projects were combined: AQEM-project (summer 2000), STAR-project (summer 2002), LAWA-project (summer 2003) and UBA-project (summer 2003) (compare Definitions – Abbreviations).

Figure 13. Distribution of near-natural sites throughout Germany, sampled with the AQEM-method (Hering et al. 2004).

The sampling sites are scattered across Germany (Figure 13), prevailing in the western mountainous areas, in the northern lowlands and in the alpine region. No samples were taken in the southern and eastern mountainous areas and in the lowlands of the far north.

Table 7. Characteristic parameters of the sites sampled with the AQEM-method; ordered by stream type number according to Pottgiesser (personal notes). (Federal State: BA = Bavaria, BB = Brandenburg; BW = Baden-Wuerttemberg; HE = Hesse; LS = Lower Saxony; NW = North Rhine-Westphalia, RP = Rhineland-Palatinate; PL= Poland; Ecoregions: 4 = Alps, 8/9 = Western/Central Sub-alpine Mountains, 14 = Central Lowlands)

Stream name	Sampling site	Federal State	River system	Ecoregion	Easting	Northing	Sampling date	Catchment area [km^2]	Altitude [m]	Stream type	Mean slope [%]
Ostrach	Hinterstein	BA	Danube	4	3606410	5260335	18.06.02	71	857	1	1.11
Lindenbach	Grafenaschau	BA	Danube	4	4433259	5280405	18.06.03	10	659	1	2.02
Hardtbach	Am Hardt	BA	Danube	9	4438669	5303540	17.06.03	19	570	3.1	1.39
Thalkirchener Ache	Unterachthal	BA	Danube	9	4520874	5303670	13.06.03	18	506	3.1	1.56
Halblech	Halblech	BA	Danube	4	4409395	5279875	18.06.03	90	766	4	1.12
Iller	Fischen	BA	Danube	4	3596770	5255740	18.06.03	200	777	4	0.70
Isar	Geretsried	BA	Danube	4	4461035	5304855	20.06.03	818	589	4	0.32
Leitzach	Riedberg	BA	Danube	4	4490485	5301465	19.06.03	172	586	4	0.91
Tiroler Achen	Schleching	BA	Danube	4	4531190	5286950	19.06.03	39	560	4	0.73
Elbrighäuser Bach	Neuludwigsdorf	HE	Weser	9	3470639	5658634	18.07.02	9	416	5	1.50
Linnepe	Linneperhütte	NW	Rhine	9	3436059	5685462	19.07.02	12	355	5	2.70
Platißbach	Eicherscheider Berg	NW	Maas	8	3316869	5596322	28.06.02	10	430	5	1.80
Prether Bach	Oberprether Mühle	NW	Maas	8	3316401	5593091	27.06.02	15	490	5	2.00
Weiße Wehe	Wehebachtalsperre	NW	Maas	8	3312688	5623966	29.06.02	15	265	5	1.37
Weiße Wehe	Hürtgen	NW	Maas	8	2524230	5619026	21.06.00	10	295	5	2.29
Kall	Lammersdorf	NW	Maas	8	2521008	5610361	23.06.00	19	460	5	2.50
Waldbach	Endorf	NW	Rhine	9	3433083	5681575	30.06.00	9	370	5	1.76
Palme	Bödefeld	NW	Rhine	9	3457342	5679956	30.06.00	10	455	5	2.14
Elbrighäuser Bach	Dodenau	HE	Weser	9	3470650	5657182	03.07.00	9	380	5	1.72
Riedgraben	Dodenau	HE	Weser	9	3470333	5656349	03.07.00	7	385	5	1.10
Laasphe	Bad Laasphe	NW	Rhine	9	3457765	5646363	03.07.00	15	375	5	2.72
Aubach	Wiesthal	BA	Rhine	9	3530800	5544665	14.06.02	40	250	5.1	0.90
Bieber	Rossbach	HE	Rhine	9	3521875	5558448	12.06.02	25	195	5.1	0.70
Hafenlohr	Lichtenau	BA	Rhine	9	3530650	5533750	14.06.02	54	280	5.1	1.30
Ilme	Relliehausen	LS	Weser	9	3547500	5737075	21.06.02	48	190	5.1	0.60
Itterbach	Kailbach	HE	Rhine	9	3506345	5490105	26.06.02	36	265	5.1	1.10
Galmbach	Kailbach	HE	Rhine	9	3506298	5489518	24.06.03	15	245	5.1	2.49

Stream name	Sampling site	Federal State	River system	Ecoregion	Easting	Northing	Sampling date	Catchment area [km^2]	Altitude [m]	Stream type	Mean slope [%]
Haslochbach	Haslochbach	BA	Rhine	9	3534640	5522419	24.06.03	17	230	5.1	1.99
Schwarzbach	Clausen	RP	Rhine	8	3409065	5461719	26.06.03	27	325	5.1	1.34
Wieslauter	Wieslauter	RP	Rhine	8	3409628	5453594	26.06.03	43	340	5.1	0.57
Rur	Wiselsley	NW	Maas	8	2520212	5602726	26.06.00	185	360	9	1.04
Nims	Birtlingen	RP	Rhine	8	2534774	5534570	20.07.00	222	245	9	0.50
Ahr	Altenahr	NW	Rhine	8	2570641	5597244	19.07.00	750	165	9	0.19
Eder	Röddenau	HE	Weser	9	3481725	5655122	30.06.00	575	280	9	0.17
Orke	Reckenberg	HE	Weser	9	3488457	5668668	29.06.00	289	280	9	0.51
Prüm	Wüstung Beifels	RP	Rhine	8	2530316	5545925	20.07.00	327	280	9	0.28
Fulda	Richthof	HE	Weser	9	3541196	5626306	10.06.02	1214	217	9.2	0.09
Fulda	Kerspenhausen	HE	Weser	9	3545992	5631034	10.06.02	1488	205	9.2	0.08
Sieg	Buisdorf	NW	Rhine	9	2586241	5628142	18.06.02	1905	56	9.2	0.14
Eder	Niedermöllrich	HE	Weser	9	3524727	5664456	08.07.02	1781	162	9.2	0.16
Jagst	Widdern	BW	Rhine	9	4312680	5467610	22.06.03	1233	191	9.2	0.40
Nahe	Monzingen	BA	Rhine	9	3398380	5518290	18.06.03	1469	157	9.2	0.28
Furlbach	Senne	NW	Ems	14	3479245	5749861	06.06.00	18	136	14	0.83
Eltingmühlenbach	Wald	NW	Ems	14	3409061	5776562	17.07.00	151	40	14	0.10
Wienbach	Naturnah	NW	Rhine	14	2569231	5728989	30.06.00	64	36	14	0.17
Aue	Wildeshausen	LS	Weser	14	3456713	5862971	31.07.02	90	20	15	0.17
Berkel	Vreden	NW	Ijssel	14	3352429	5767086	29.07.02	240	31	15	0.11
Eltingmühlenbach	Greven	NW	Ems	14	3408967	5776509	29.07.02	151	47	15	0.10
Lachte	Lachendorf	LS	Weser	14	3580388	5833171	01.08.02	440	41	15	0.09
Örtze	Poitzen	LS	Weser	14	3576023	5864583	01.08.02	200	66	15	0.07
Rhin	Rägelsdorf	BB	Elbe	14	3762159	5882005	16.07.02	260	74	15	0.09
Stepenitz	Putlitz	BB	Elbe	14	3703777	5908102	15.07.02	177	52	15	0.14
Stepenitz	Telschow	BB	Elbe	14	4506795	5908082	27.06.00	151	60	15	0.14
Stepenitz	Porep	BB	Elbe	14	4503262	5903411	26.06.00	177	52	15	0.11
Rhin	Rägelsdorf	BB	Elbe	14	4560852	5875234	29.06.00	241	60	15	0.15
Ilanka	Grenze	PL	Elbe	14	5479642	5794068	01.07.00	490	40	15	0.05
Pliszka	Grenze	PL	Elbe	14	5482132	5790597	01.07.00	320	25	15	0.05
Stepenitz	Perleberg	BB	Elbe	14	4491459	5884377	27.06.00	751	30	15	0.07

Stream name	Sampling site	Federal State	River system	Ecoregion	Easting	Northing	Sampling date	Catchment area [km^2]	Altitude [m]	Stream type	Mean slope [%]
Rhin	Rheinshagen	BB	Elbe	14	4560621	5878817	29.06.00	222	40	15	0.15
Dahme	Dahme	BB	Elbe	14	5410678	5770134	28.06.00	550	45	15	0.14
Lippe	Klostermersch	NW	Rhine	14	3447015	5725556	16.06.03	1818	71	15.2	0.05
Ems	Fuestrup	NW	Ems	14	3411615	5767421	16.06.03	1898	46	15.2	0.03
Hunte	Dötlingen	LS	Ems	14	3457507	5866843	03.06.03	1660	15	15.2	0.05
Spree (Schiwastrom)	Schlepzig	BB	Elbe	14	5423050	5768355	11.06.03	4528	45	15.2	0.05
Spree (Müggel-)	Sieverslake	BB	Elbe	14	5419721	5803466	11.06.03	6476	33	15.2	0.02
Wurm	Wildnis	NW	Maas	8	2505550	5639129	28.06.02	175	100	17	0.39
Schwalm	Grenze	NW	Maas	14	2504615	5677438	15.07.02	265	26	17	0.23

Pottgiesser (personal notes) assigned the streams to the following stream types according to the list of Sommerhäuser & Pottgiesser (2004; Appendix 1 and 2): 1, 3 (both sampled by Research Institute Senckenberg), 5 (University of Duisburg-Essen), 5.1 (Research Institute Senckenberg), 9 (University of Duisburg-Essen), 9.2 (University of Duisburg-Essen and Research Institute Senckenberg), 14, 15, 15.2 and 17 (all four by the University of Duisburg-Essen). The sites were preclassified by expert judgement to be in a high or good ecological status. As another criterion the assessment with the stream type specific saprobic index (Rolauffs et al. 2003) had to result in "good" or "high" status.

All organisms sampled were identified to genus or species level, except for some Diptera families and Oligochaeta, which were identified to a range between species and family level. Further on, a taxonomical adjustment at species level was performed to delete identification level differences. Chironomidae and Oligochaeta were summed up to family and order level respectively. The abundances of the complete taxa lists were log (x+1) transformed to minimise overrating of high abundances of single taxa (e.g. *Gammarus* sp.).

Method

Non-metric Multidimensional Scaling (NMS; compare Chapter 1.1.2) was performed with the following overlays for interpretation: altitude of the sampling site, ecoregion according to Illies (1978), catchment size, geology, number of taxa, stream type according to Sommerhäuser & Pottgiesser (2004). A cluster analysis with Soerensen Index as the distance measure and Flexible Beta (Beta value = – 0.25) as linkage method centres the analysis. As an additional similarity analysis, the cluster analysis confirms the graphical grouping of the (dis)similarity analysis of the NMS. The resulting groups were used as overlays for the main interpretation of the results. Ten cluster groups were chosen as the golden mean to account for the major differences but not all of the variance in the data.

The NMS was performed several times and the results remained stable.

1.3.3 Results

The following diagrams display the NMS results of the taxa lists together with abiotic parameters and the results of a cluster analysis as different overlays. With an overall stress of 14.9 % a two-dimensional solution was chosen, where the two axes together explain 82.2 % of the variance in the data set.

In Figure 14 the blue triangles in the upper area indicate sampling sites with altitudes ≤ below 100 m above sea level located in the northern German lowlands. The lower mountainous regions are represented by green triangles with elevations between 100 and 500 m above sea level. Samples located in the lower part of the diagram originate from the alpine area (red and black triangles).

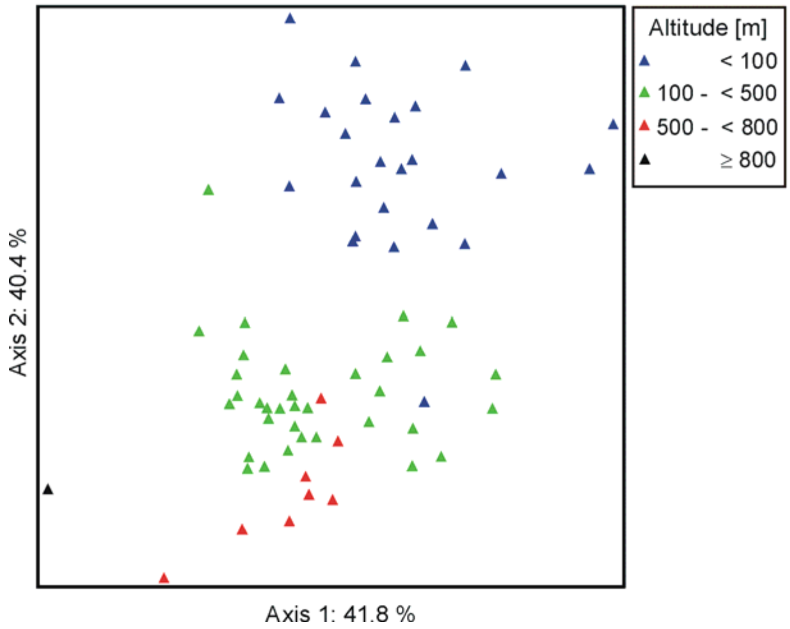


Figure 14. NMS diagram for 67 near-natural sites sampled with the AQEM-method. Overlay: Altitude (m a.s.l.).

Thus, there is a direct correlation of the altitude with the second axis. Altitude was one of the major abiotic factors for Illies (1978) to distinguish ecoregions. Subsequently a separation of the samples by ecoregions is obvious (Figure 15).

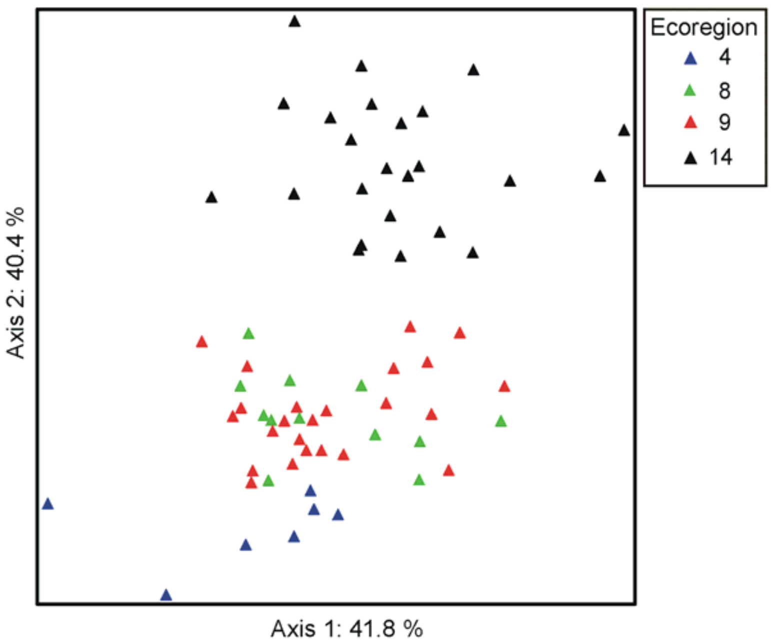


Figure 15. NMS diagram for 67 near-natural sites sampled with the AQEM-method. Overlay: Ecoregion (4 = Alps, 8 = Western Sub-alpine Mountains, 9 = Central Sub-alpine Mountains, 14 = Central Lowlands).

Samples from the lowlands form a distinct group in the upper part of the diagram. On the other hand, samples of the two mountainous regions (ecoregion 8 and 9) completely mix. Even the division of alpine samples from the lower mountainous ones is not self-evident. The third overlay displays the size of the catchment (Figure 16): Small catchments are located in the left and middle part of the diagram and large catchments in the right part, showing a direct correlation to the first axis. This sequence is visible in the mountain as well as in the lowland samples. The size classes follow the proposal of the EU Water Framework Directive except for the second category, where 200 km^2 were chosen instead of 100 km^2, since in the lowlands this borderline shows a much clearer distinction between small size stream and larger ones. For the samples of the mountain streams this borderline is not a differentiating parameter, as the catchment area of the sampling sites is always below 100 km^2 (see Table 7).

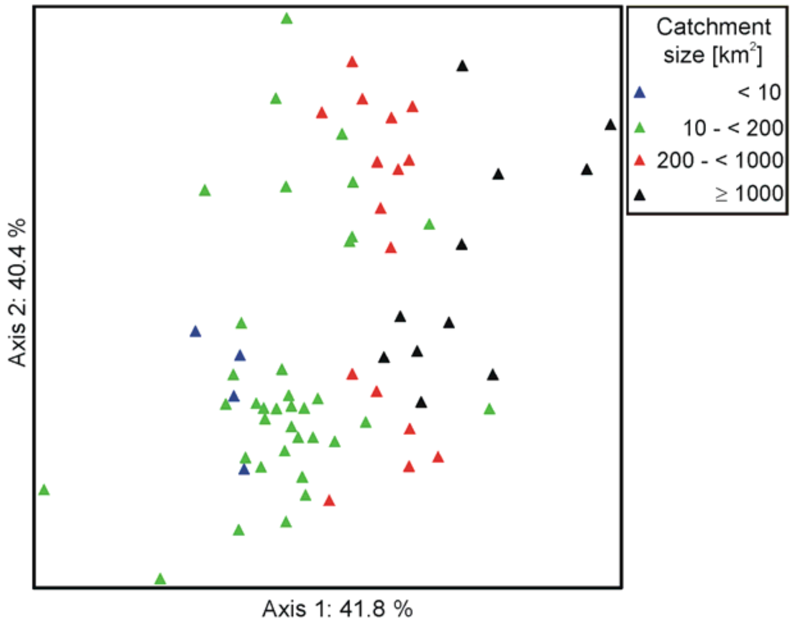


Figure 16. NMS diagram for 67 near-natural sites sampled with the AQEM-method. Overlay: Size of the catchment area (km^2).

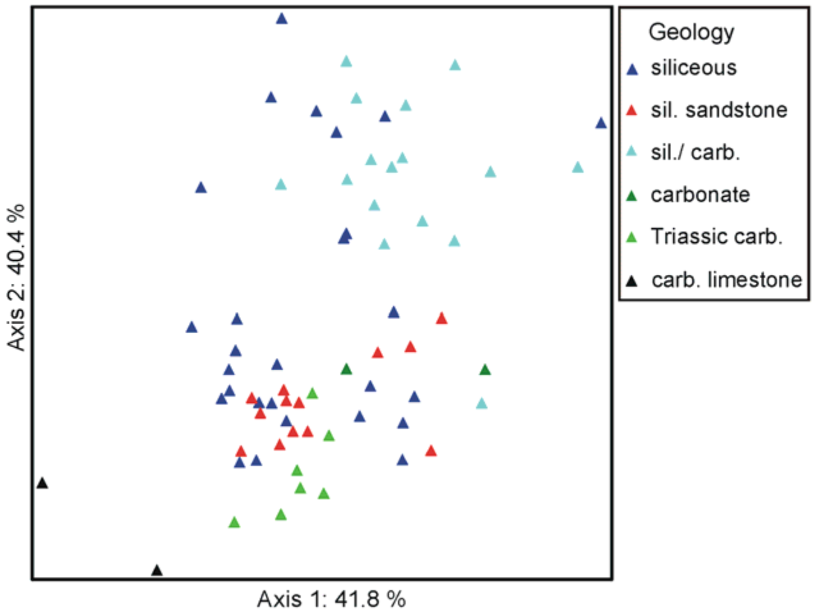


Figure 17. NMS diagram for 67 near-natural sites sampled with the AQEM-method. Overlay: Geology. (sil. = siliceous, carb. = carbonate)

For classifying the geology of the sampling sites (Figure 17) broad categories (siliceous, carbonate) were chosen, which Braukmann (1987) and LUA (1999) considered as biocoenotically relevant. Obviously, two samples of the (carbonate) limestone Alps stand alone in the lower left part. Close to them are five samples from lower parts of the Triassic (carbonate) Alps (green triangles).

The siliceous schist (blue) and sandstone (red) sites are mixed, both in the small and in the larger catchments.

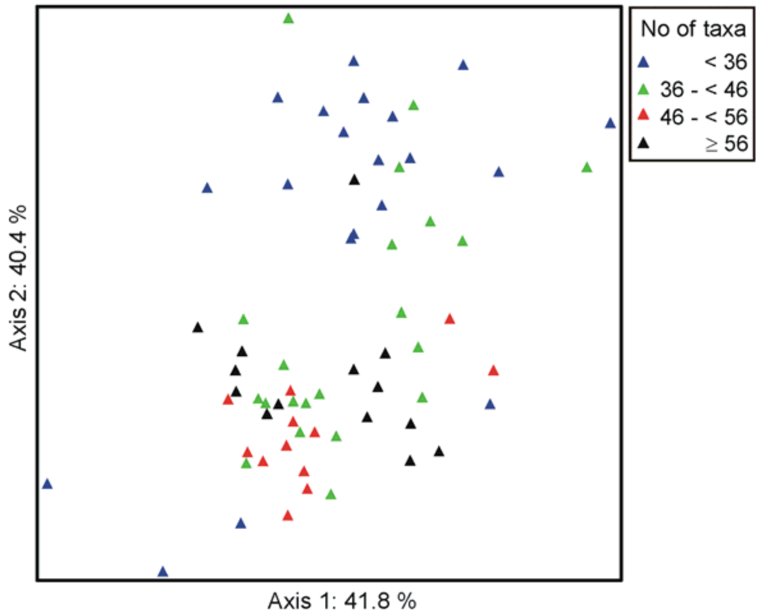


Figure 18. NMS diagram for 67 near-natural sites sampled with the AQEM-method. Overlay: Number of taxa.

In the lowlands (upper part of the plot) the purely siliceous sites are located on the left part and the siliceous/carbonate sites more on the right part of the diagram. The overlay "Number of taxa" shows a gradient from the lowland to the mountain samples (Figure 18). The correlation between the number of taxa and the second axis is obvious.

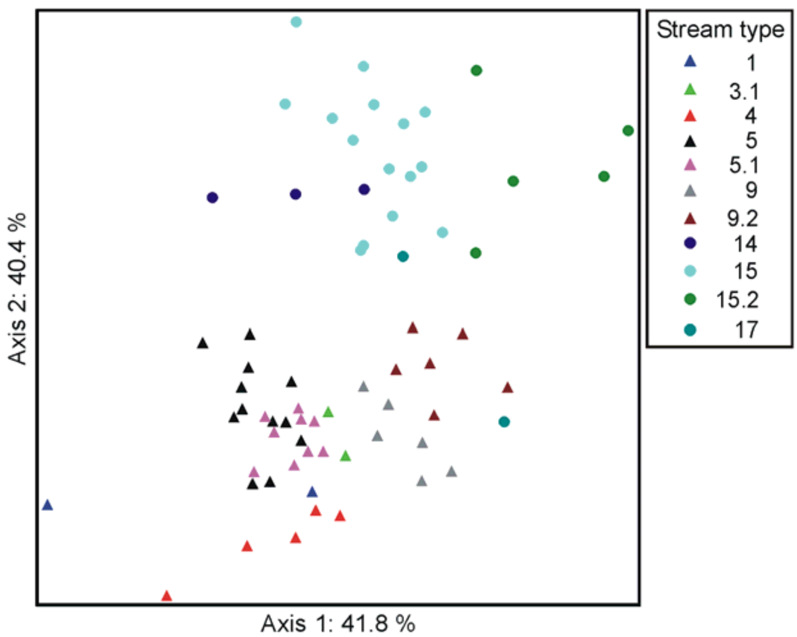


Figure 19. NMS diagram for 67 near-natural sites sampled with the AQEM-method. Overlay: Stream type according to Sommerhäuser & Pottgiesser (2004).

The small (type 14), mid-sized (type 15) and large (type 15.2) sand bottom lowland stream types according to the German stream typology (Sommerhäuser & Pottgiesser 2004) are well partitioned in Figure 19. The two type 17 sites (mid-sized gravel bottom lowland streams) mix on the one hand with type 15 and on the other hand with the large mountain streams (type 9.2). The assignments of the lower mountain streams resemble the size gradient from the left side (small streams; type 5 and type 5.1) over the middle (mid-sized streams; type 9) to the right side (large streams, type 9.2). The two samples of the type 3.1 streams (streams in the Pleistocene sediments of the alpine foothills) are located in between the small and mid-sized mountain streams. The large streams of the alpine foothills (type 4) mix with the alpine streams (type 1), but are separate from the lower mountain stream types. Mainly the alpine and the lowland sites differ in their assignment to the cluster analysis grouping.

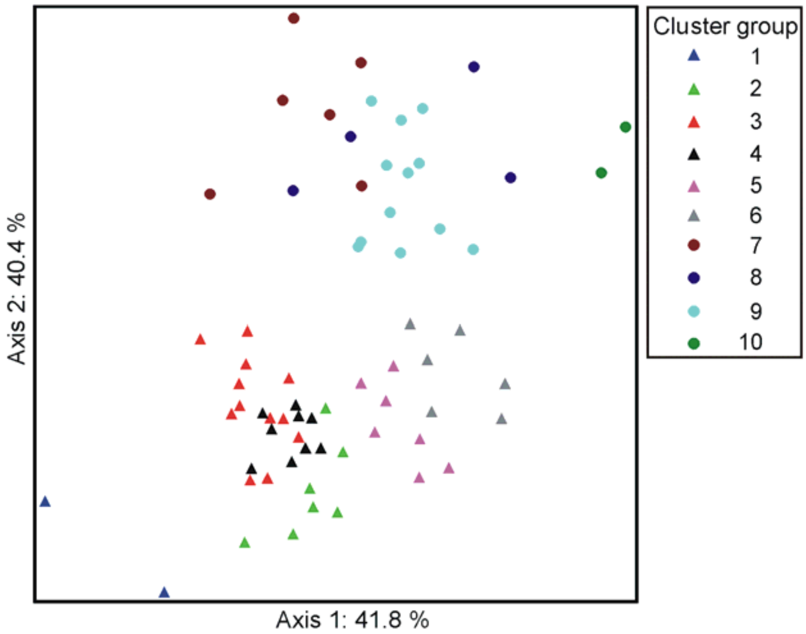


Figure 20. NMS diagram for 67 near-natural sites sampled with the AQEM-method. Overlay: Cluster groups derived by the cluster analysis with the faunal assemblages.

Figure 20 depicts the results of the cluster analysis as an overlay, where different colours and/or different symbols represent the cluster groups. Cluster group 1 consists of two samples of the limestone Alps. Cluster group 2 unites the lower alpine areas. The black triangles (cluster group 4) comprise siliceous sandstone samples although they mix in the diagram with the (red) siliceous schist sites (cluster group 3). Cluster group 5 represents mid-sized mountain streams followed on the right side of the diagram by cluster group 6, which represents large mountain streams. In the upper part of the diagram cluster group 7 combines small mainly siliceous lowland streams. Cluster group 8 is composed of two mid-sized and two large lowland streams with a siliceous/carbonate geology, while cluster group 9 comprises mid-sized sand bottom lowland streams. The last cluster group (two samples of large lowland streams) is located in the outer right part of the diagram.

Figure 21 combines and portrays in a joint plot the results of the NMS analysis and main parameters determining the distribution of the samples.

Figure 21. NMS joint diagram for 67 near-natural sites sampled with the AQEM-method and four major gradients. The length of the vectors visualise their correlation with the data set. Overlay: Ecoregion of the sampling sites. (4 = Alps, 8 = Western Sub-alpine Mountains, 9 = Central Sub-alpine Mountains, 14 = Central Lowlands)

1.3.4 Discussion

The results of the NMS analysis resemble the results of Chapter 1.1. In comparison, the data set is smaller and not all regions and *a priori* defined stream types are present. However, the consistency of the sampling, sorting and identification process forms the basis for more distinct groups of samples and thus of stream types.

The differences between stream types are obvious, although only summer samples have been taken into account and consequently, due to spring emergence, major key taxa (e.g. many Plecoptera species) were not present anymore. Another important issue when comparing this data set to the water authority monitoring data (data set in Chapter 1.1) is the level of taxa identification. The work of the skilled identifiers of the Research Institute Senckenberg and University of Duisburg-Essen resulted in taxa numbers, which are nearly three times as high as the taxalists used in Chapter 1.1. Only to a minor degree this can be explained by the reduction to the groups EPTCOM of the data set in Chapter 1.1.

More than 80 % of the variance in the data set is explained by the two axes of the NMS plot. In combination with the low stress (14.9 %) the ordination of the samples in this two-dimensional space therefore gives a clear view on the actual differences and distances between the samples.

Major faunal differences between the ecoregions of the German lowlands and the mountainous regions (lower mountainous areas as well as Alps) can be seen in each of the NMS diagrams in the big gap between the samples of the lowlands and the mountainous regions. The nearly direct negative correlation of altitude and number of taxa to the second axis is a sure sign for these differences (Figure 21). Although Illies (1978) has chosen the 500 m-line as the borderline between lowlands and mountainous regions the data here suggest that the 100 m-line would be more suitable. The 500 m-borderline can be proposed for the partitioning of lower and higher mountainous areas. Above 800 m the alpine region adjoins the higher mountainous areas (Illies 1978: 1000 m-line).

The slope of the valley floor depicted as a vector in Figure 21, also visualises different characteristics of lowland and mountain streams. The second major gradient in the data (correlating with the first axis) is the size of the catchment area respectively the distance to the source. Waite et al. (2000) also found that "macroinvertebrates seem to respond primarily to slope and stream order and then to the landscape factors summarised by ecoregion". Thus, several species are not stream type specific but stream size specific and can be found in the lowlands as well as in the mountains but in streams of similar size.

Mean current velocity as another main gradient in providing habitat for the macroinvertebrate fauna was not measured at the sampling sites but can be derived from the slope and thus, is likely to correlate with this vector.

Catchment geology is a discriminating factor mainly in samples taken in the mountainous regions. This adds some explanatory power to the cluster groups. Comparing the classification of the sampling sites according to the typology of Sommerhäuser & Pottgiesser (2004) to the cluster groups, major correspondence can be seen in the assignment of the mountain sites to the size classes, but disagreements are visible in the alpine and lower alpine sites as well as the smaller lowlands sites. These stream types were assigned only on the basis of geomorphological maps irrespective of the faunal composition. Merging the abiotic factors altitude, ecoregion, catchment size and geology used by Sommerhäuser & Pottgiesser (2004) with the benthic macroinvertebrate community used in this study an integrated approach is proposed to stream typology. In the data set presented here, this approach leads to the following stream type classification:

Within ecoregion 4 (Alps) two distinct groups are distinguishable: on the one hand high alpine calcareous limestone streams (with altitudes above and around 800 m a.s.l.) and on the other hand lower alpine carbonate streams (altitudes above 500 m but below

800 m a.s.l.). Species like *Perla grandis*, different *Liponeura* taxa and species of the *Rhithrogena hybrida*-group and *R. diaphana*–group were found only in these stream types. The two genera *Liponeura* (family Blephariceridae) and *Rhithrogena* (family Heptageniidae) are adapted to high current velocity, which is omnipresent in the Alps due to steep slopes. Both feed on algae growing on pebbles in the highest currents of up to 2 m/s. While *Liponeura* walks with 6 suckers on the pebbles (Frutiger & Jolidon 2000) *Rhithrogena* has an enlarged first gill, which also acts as a sucker and keeps the organisms attached to the surface. The absence of genera such as *Hydropsyche* or *Hydraena* is also typical for the high alpine cluster, separating it from the lower alpine cluster. The feeding nets of *Hydropsyche* probably do not resist the high current velocities or the amount of fine particulate organic matter is too low to survive. The preferred habitat of *Hydraena* species are mosses (Schmedtje & Colling 1996), which are scarce in high alpine streams. Crustacea taxa are missing in the complete alpine samples, leading to a separation from the mountain sites where especially *Gammarus* species can be very abundant. Because of the high channel dynamics woody riparian vegetation is scarce and thus, the supply of leaves – the main food of the Crustacea – is reduced. Two sites, which had been assigned to stream type 3.1 ("Streams in the pleistocene sediments of the alpine foothills") by Sommerhäuser & Pottgiesser (2004) have a bit of both, alpine fauna and lower mountain fauna. A clear classification for these two sites is not possible with the suggested approach (Figure 19). The small mountain streams with catchment areas between 8 and 100 km^2 and altitudes between 150 and 500 m above sea level (Table 7) form a distinct group spanning over two ecoregions (Western and Central Sub-alpine Mountains). However, if catchment geology and the results of the cluster analysis are considered, two clear stream types can be divided: siliceous schist streams and siliceous sandstone streams. Both of them are inhabited by large numbers of the same species but some differences in taxonomic composition and species abundance are clearly visible. The larvae of the beetle *Hydrocyphon deflexicollis* and the stonefly *Perla marginata* were found only in samples of schist streams. In contrary, representatives of the caddisfly family Brachycentridae (especially *Micrasema minimum*) need the sandy particles of the sandstone streams for their caddises. Among the order Ephemeroptera *Alainites muticus* and *Baetis vernus* are only present in samples of the sandstone streams, while *Epeorus sylvicola* and *Habrophlebia* sp. seem to prefer schist streams, where they find more, larger stones. Early instars of the genus *Habrophlebia* inhabit the interstitial (Haybach 1998), which is clogged up by the fine sand particles in the sandstone streams. Crustaceans like *Gammarus fossarum* can be found eventually in schist streams, but their numbers are threefold in sandstone streams. Opposite to that, the filter-feeding species of the family

Philopotamidae (Trichoptera; e.g. *Philopotamus montanus* and *P. ludificatus* or *Wormaldia occipitalis*) are far more abundant in the schist streams, possibly because they need stones to span their nets and higher currents for food supply (Moog 1995). Grains of sand destroy their nets too often in sandstone streams. On the other hand, high current velocity in the schist streams leads to a frequent washout of coarse particulate organic matter (CPOM), which is the main food source of *Gammarus*. In the slow flowing sandstone streams CPOM accumulates and supports a much more abundant Gammarus community. Spanning the NMS diagrams (e.g. Figure 16) from left to right is like following the river continuum downstream. Along the size gradient of mountain streams different faunal assemblages are supported, because of the change in several abiotic factors like slope, shading or thermal conditions. The thermal gradient has not been classified but it is subliminal in the diagram from the Alps to the lowlands as well as from the small streams to the large ones. In the mountain streams with a catchment area between 100 and 1000 km^2 the mean slope of the valley floor drops again in comparison to the smaller streams (Table 7). Nevertheless, a wide range of current velocities and habitats due to a high substrate diversity exists and supports the highest numbers of taxa in the entire data set (Figure 18). This stream zone is a melting pot of rhithral as well as potamal faunal elements each of them attracted by certain habitats. The separation of mid-sized and large mountain streams (cluster groups 5 and 6, respectively stream types 9 and 9.2) is easily supported. For a detailed analysis of these two stream types see the following chapter. In contrast to the small streams the geology of the sampling sites is of subordinate importance. Most of the large mountain streams are carbonate streams but the fauna does not reflect the calcareous character.

The lower right triangle of this cluster group (6; Figure 19) forms the transition to the lowland samples. This sample has been collected at a site on the borderline between lowlands and mountainous regions (Table 7; river Wurm). The faunal assemblage suggests it as a large mountain stream community but the abiotic factors (altitude: 100 m a.s.l., catchment area: 175 km^2, substrate: gravel and sand) characterise the site as a lowland gravel-bed stream. Thus, higher currents and a more gravelly substrate than in lowland streams form the habitats for a "mountain-minded" community.

Cluster group 7 comprises small, mainly siliceous sand bottom lowland streams. The leading and abundant species is the sand burrowing mayfly *Ephemera danica*. The caddisflies *Anabolia nervosa* and *Chaetopteryx villosa* are also frequently occurring. In the sinuate and shaded river channels moderate flow velocities do not leave much room for lentic conditions, which are preferred by Oligochaeta. Stands of mosses and submerged macrophytes are also not found but present an important habitat, e.g. for beetles such as *Elmis* sp. and *Limnius* *volckmari*, which were collected in the sampling sites of cluster group 9. In these mid-sized sand bottom lowland streams (cluster group 9) the channel width is broader than in the sites of cluster group 7 and thus, not the entire water surface is shaded. The shallow slope leads to a meandering channel form (Einstein 1926), which slows down the current velocity allowing macrophyte growth. Woody debris provides a surface for mosses and algae, which are grazed by *Heptagenia* sp. (mainly *H. flava*) replacing *E. danica* as the dominant mayfly. Other abundant potamophilic species are *Aphelocheirus aestivalis* (Heteroptera), *Gomphus vulgatissimus* (Odonata) or *Brachycentrus subnubilus* (Trichoptera). Cluster group 8 is the connecting link between the mid-sized and the large lowland streams. Two groundwater fed mid-sized and two large lowland streams with a siliceous/carbonate geology form this group and their faunal composition is characterised by species like *Brachycercus harrisella* (Ephemeroptera) but also by the absence of e.g. *Halesus* sp. (Trichoptera) or *E. danica*.

Corophium curvispinum (Crustacea) and *Leptocerus interruptus* (Trichoptera) are examples for inhabitants of large sand bottom lowland streams. These taxa are potamobiont and need the warm and slow flowing waters, which also support the presence of *Caenis macrura* (Ephemeroptera) and *C. pseudorivulorum* and species of the caddisfly genus *Hydroptila*. Thus, a thermal gradient, which is a function of distance to source and mean slope of the valley floor, seems to determine the occurrence of species in the lowland streams.

1.4 Differences and similarities of mid-sized and large mountain streams

1.4.1 Introduction

The results of Chapter 1.3 showed clear differences in the benthic invertebrate communities of stream types. Abiotic parameters of the sampling sites varied, too (Table 7). However, in the focus of Chapter 1 is the biotic component whereby abiotic parameters only serve as explaining variables. The presence/absence or abundance of taxa in a sample assigns a site to a particular stream type; the classification is based on the faunal assemblage (compare Chapter 1.3.3). Species occur only in those reaches, which fit into their ecological niche. On account of the occurrence of species conclusions can be drawn on: (1) the stream type and (2) the habitat; by analysing abiotic parameters of the sites the needs of the biota concerning substrate, temperature, stream zone, current or diet become obvious.

Key indicator lists for stream types would help water authorities to assign (by comparison) a site to a stream type. If key indicator lists derive only from near-natural sites these taxa lists can also serve as the reference status for assessment systems. Thus, by the comparison of existing taxa lists of a site with a "reference status list" degradations could become evident. Further on, by an analysis of the autecological preferences of the key taxa degradations or losses of the habitat would become apparent.

To detect these key indicator taxa exemplarily the mid-sized and large mountain streams were chosen. The data set of near-natural or only slightly degraded sites is fairly large and the identification was mainly to species level. This is the pre-condition for indicator species detection.

Thus, the following questions are addressed:

- What are the key indicator taxa for the mid-sized streams of lower mountainous areas in Germany?
- What are the key indicator taxa for the large streams of lower mountainous areas in Germany?

1.4.2 Characterisation of mid-sized and large mountain streams in Germany

The abiotic characterisations of the predefined stream types mid-sized (stream type 9) and large (stream type 9.2) streams in lower mountainous areas (Sommerhäuser & Pottgiesser 2004) are displayed in Table 5 and Table 11. The main difference is the size of the catchment area and the altitude of the sampling sites, which ranges for the mid-sized streams between 200 and 360 m above sea level (exception: the river Ahr at 156 m) and for the large streams between 56 and 220 m above sea level (exception: river Werra at 267 m). The steeper slope in mid-sized streams presumably leads to stronger currents and a higher current diversity.

The geological formation is homogeneous and consists of siliceous schist. With the exception of three sites (Rur/Wiselsley, Nims/Birtlingen and Jagst/Widdern), which are anabranching (e.g. Figure 25), single thread channels, which flow sinuately through their floodplain, were investigated. Floodplain width ranges from 30 to 100 m in the mid-sized streams and from 100 to 300 m in the large streams. The main channels are between 1 and 3 m incised into the siltated floodplains. The siltation was caused during the middle ages due to clear cutting of most of the forests of the Central European mountainous areas for fire wood and for gaining arable land (Küster 1998). Rainfall washed the top soil into the floodplains and thus, filled the interstices of the formerly gravel-bedded plains and, depending on the area, piled up to 3 m (Küster 1999). Egg- to hand-sized pebbles (Makrolithal) dominate the substrates with small proportions of sand (Psammal), gravel (Akal) and boulders (Megalithal), shifting to the smaller grain-size in the large streams. Stands of *Potamogeton* sp. and *Ranunculus fluitans* and patches of bryophytes occur as well as debris accumulations (Figure 26), depending on the shading and the "channel cleaning" of regional water management. Reference conditions for these stream types are described in LUA (1999, 2001) and Pottgiesser & Sommerhäuser (2004) (see also Figure 25 and Figure 26).

1.4.3 Materials and methods

Database

Information on sampling sites, sampling and data processing are given in Chapter 1.2.2 and Table 5. The classification of the best discriminating taxonomic and abundance resolution (i.e. complete faunal community, species level and log (x+1) transformed abundances) served as the starting point. The assignment of the samples to the two stream type groups according to the results of the cluster analysis determined the grouping in the IndVal calculations.

The stream Eder at Niedermöllrich was counted to the mid-sized mountain streams (stream type 9), because of the results of the cluster analysis (Chapter 1.3).

Indicator Value analysis

An IndVal analysis (Indicator value; Dufrêne & Legendre 1997) was performed on the samples, which have also been used for the taxonomic resolution analysis (Chapter 1.2). This analysis detects species, which characterise sample groups. It calculates proportional abundances of species in predefined groups (in this case the predefined stream types) and relates those to the abundance of that species in all groups. Afterwards, the proportional frequency of the species in each group is calculated. Finally, abundances and frequencies are multiplied. The results are expressed as a percentage, yielding an indicator value "IV" for each species in each group. The group, for which the species gets the highest indicator value is displayed. Afterwards, the statistical significance of the IV is tested by a Monte Carlo simulation.

The indicator values range from 0 (no indication) to 100 (perfect indication). Perfect indication is assigned to species present in all samples of a particular group.

1.4.4 Results

Table 8 and Table 9 display the indication values of the species for the two stream types sorted by the indicator values with highest scores on top. The Monte Carlo simulation for significance of the individual indicator values (column "p") shows best results for high "IV".

17 taxa are significant indicator taxa for the mid-sized mountain streams (stream type 9) with $p < 0.01$ and 30 taxa with $p < 0.05$. In contrast, only 5 taxa are significant with $p < 0.01$ in the large mountain streams (stream type 9.2) and 10 with $p < 0.05$. The highest IV (92.4) was calculated for the Trichoptera genus *Sericostoma* in stream type 9, followed by *Leuctra geniculata* (Plecoptera; 75.9) and *Ancylus fluviatilis* (Gastropoda; 74.7) in the same stream type. In stream type 9.2 the Ephemeroptera *Baetis fuscatus* (73.3) head the list followed by the Bivalvia genus *Pisidium* (68.2).

Table 8. Indicator values (IV) and significance level (p) for Monto Carlo Test of significance for the indicator taxa of the mid-sized mountain streams (stream type 9); ordered by the IV. (Co = Coleoptera; Cr = Crustacea; Di = Diptera; Ep = Ephemeroptera; Ga = Gastropoda; He = Heteroptera; Hi = Hirudinea; Me = Megaloptera; Pl = Plecoptera; Tc = Trichoptera; Tu = Turbellaria)

Group	Taxon	Author	IV	p
Tc	Sericostoma sp.		92.4	0.001
Pl	Leuctra geniculata	(STEPHENS, 1836)	75.9	0.001
Ga	Ancylus fluviatilis	O.F. MÜLLER, 1774	74.7	0.001
Ep	Ecdyonurus venosus-Gr.		73.0	0.001
Hi	Erpobdella sp.		71.0	0.005
Ep	Baetis scambus	EATON, 1870	70.0	0.005
Di	Pedicia sp.		69.2	0.002
Tc	Polycentropus flavomaculatus	(PICTET, 1834)	67.9	0.003
Ep	Ecdyonurus sp.		66.3	0.005
Tc	Rhyacophila sp.		66.1	0.001
Co	Hydraena gracilis Ad.	GERMAR, 1824	64.3	0.018
Ep	Baetis lutheri	MÜLLER-LIEBENAU, 1967	63.7	0.004
Hi	Glossiphonia sp.		61.9	0.005
Pl	Leuctra sp.		61.7	0.001
Di	Rhagionidae Gen. sp.		61.5	0.003
Tc	Allogamus auricollis	(PICTET, 1834)	61.5	0.003
Tc	Rhyacophila dorsalis	(CURTIS, 1834)	61.5	0.005
Ep	Baetis rhodani	PICTET, 1843-1845	61.0	0.045
Di	Atherix ibis	(FABRICIUS, 1798)	58.2	0.047
Co	Elmis aenea/maugetii Ad.		55.9	0.018
Tc	Rhyacophila fasciata	HAGEN, 1859	54.5	0.006
Tc	Hydropsyche siltalai	DÖHLER, 1963	53.3	0.124
Co	Oulimnius tuberculatus Ad.	(MÜLLER, 1806)	52.5	0.365
Di	Simulium sp.		52.4	0.357
Ep	Ecdyonurus dispar	(CURTIS, 1834)	51.8	0.068
Tc	Hydropsyche incognita	PITSCH, 1993	48.1	0.124
Cr	Gammarus pulex	(LINNAEUS, 1758)	47.0	0.138
Di	Prosimulium sp.		46.2	0.011
Tc	Chaetopteryx villosa	(FABRICIUS, 1789)	46.2	0.014
Tc	Micrasema minimum	McLACHLAN, 1876	46.2	0.015
Ep	Epeorus sylvicola	(PICTET, 1865)	46.2	0.017
Me	Sialis lutaria	(LINNAEUS, 1758)	46.2	0.021
Hi	Helobdella stagnalis	(LINNAEUS, 1758)	39.8	0.060
Tc	Anabolia nervosa	(CURTIS, 1834)	38.5	0.033
Tc	Anomalopterygella chauviniana	(STEIN, 1874)	38.5	0.036
Co	Hydraena dentipes Ad.	GERMAR, 1844	38.5	0.037
Tc	Odontocerum albicorne	(SCOPOLI, 1763)	38.5	0.037
Co	Esolus sp. Lv.		38.3	0.398
Tc	Agapetus ochripes	CURTIS, 1834	36.7	0.142
Tc	Brachycentrus maculatus	(FOURCROY, 1785)	33.4	0.098
Tu	Turbellaria Gen. sp.		33.1	0.249
Ep	Ephemera danica	MÜLLER, 1764	31.9	0.736
Co	Limnius perrisi Ad.	(DUFOUR, 1843)	30.8	0.089
Tc	Silo piceus	(BRAUER, 1857)	30.8	0.093

Group	Taxon	Author	IV	p
Pl	Perla burmeisteriana	CLAASSEN, 1936	30.8	0.094
Ep	Caenis rivulorum	EATON, 1884	30.8	0.095
Ep	Habrophlebia sp.		30.8	0.105
Co	Hydraena reyi Ad.	KUWERT, 1888	30.8	0.114
Co	Limnius opacus Ad.	MÜLLER, 1806	27.4	0.240
Tc	Hydropsyche pellucidula	(CURTIS, 1834)	23.7	0.366
Tc	Halesus radiatus	(CURTIS, 1834)	23.1	0.195
Pl	Protonemura sp.		23.1	0.213
Tc	Potamophylax luctuosus	(PILLER & MITTERPACHER, 1783)	23.1	0.216
Tc	Micrasema setiferum	(PICTET, 1834)	23.1	0.226
Tc	Philopotamus sp.		23.1	0.226
Ep	Habroleptoides confusa	SARTORI & JACOB, 1986	23.1	0.228
Tc	Halesus tesselatus	(RAMBUR, 1842)	23.1	0.232
Di	Ibisia marginata	(FABRICIUS, 1781)	23.1	0.240
Co	Elmis rioloides Ad.	KUWERT, 1890	22.0	0.287
Ga	Radix sp.		21.8	0.403
Pl	Isoperla sp.		20.7	0.339
Ga	Potamopyrgus antipodarum	(GRAY, 1843)	20.1	0.348
Tc	Mystacides azurea	(LINNAEUS, 1761)	20.0	0.481
Tc	Hydroptila sp.		20.0	1.000
Ep	Caenis beskidensis	SOWA, 1973	18.5	0.387
Ep	Caenis macrura	STEPHENS, 1835	18.4	0.702
Tc	Athripsodes bilineatus	(LINNAEUS, 1758)	16.3	0.626
Co	Esolus parallelepipedus Ad.	(MÜLLER, 1806)	16.3	0.953
Tc	Annitella obscurata	(McLACHLAN, 1876)	15.4	0.462
Tc	Agapetus fuscipes	CURTIS, 1834	15.4	0.477
Ep	Cloeon sp.		15.4	0.482
Ep	Caenis pseudorivulorum	KEFFERMÜLLER, 1960	15.4	0.485
Tc	Hydropsyche instabilis	(CURTIS, 1834)	15.4	0.485
Tc	Halesus digitatus	(SCHRANK, 1781)	15.4	0.495
Tc	Chimarra marginata	(LINNAEUS, 1767)	15.4	0.495
Ep	Ecdyonurus torrentis	KIMMINS, 1942	15.4	0.497
Pl	Perla marginata	(PANZER, 1799)	15.4	0.497
Tc	Micrasema longulum	McLACHLAN, 1876	15.4	0.497
Ep	Baetis buceratus	EATON, 1870	13.6	0.729
Ep	Centroptilum luteolum	(MÜLLER, 1776)	12.2	0.473
Tc	Ceraclea sp.		12.2	0.473
Ep	Rhithrogena sp.		12.2	0.659
Tc	Mystacides longicornis/nigra		12.1	0.602
He	Gerris sp.		10.3	0.725
Tc	Oecetis testacea	(CURTIS, 1834)	10.1	0.725

Table 9. Indicator values (IV) and significance level (p) for Monto Carlo Test of significance for the indicator taxa of the large mountain streams (stream type 9.2); ordered by the IV. (Bi = Bivalvia; Co = Coleoptera; Cr = Crustacea; Di = Diptera; Ep = Ephemeroptera; Ga = Gastropoda; He = Heteroptera; Hi = Hirudinea; Ne = Nematomorpha; Od = Odonata; Tc = Trichoptera)

Group	Taxon	Author	IV	p
Ep	Baetis fuscatus	(LINNAEUS, 1761)	73.3	0.002
Bi	Pisidium sp.		68.2	0.006
Cr	Gammarus roeselii	(GERVAIS, 1835)	66.7	0.002
He	Aphelocheirus aestivalis	(FABRICIUS, 1794)	66.7	0.002
Cr	Asellus aquaticus	(LINNAEUS, 1758)	59.0	0.012
Tc	Psychomyia pusilla	(FABRICIUS, 1781)	56.2	0.109
Tc	Athripsodes albifrons	(LINNAEUS, 1758)	52.9	0.082
Ep	Serratella ignita	(PODA, 1761)	52.7	0.289
Co	Limnius volckmari Ad.	(PANZER, 1793)	52.1	0.316
Ep	Heptagenia sulphurea	(MÜLLER, 1776)	50.0	0.002
Hi	Piscicola sp.		45.0	0.026
Tc	Brachycentrus subnubilus	CURTIS, 1834	44.6	0.114
Tc	Cheumatopsyche lepida	(PICTET, 1834)	41.8	0.412
Ga	Bithynia tentaculata	(LINNAEUS, 1758)	41.7	0.015
Ep	Potamanthus luteus	(LINNAEUS, 1767)	41.7	0.021
Cr	Gammarus fossarum	KOCH in PANZER, 1836	40.2	0.354
Tc	Lepidostoma hirtum	(FABRICIUS, 1775)	39.5	0.879
Ep	Baetis vernus	CURTIS, 1834	38.0	0.339
Ep	Caenis luctuosa	(BURMEISTER, 1839)	36.2	0.423
Di	Dicranota sp.		35.2	0.901
Tc	Athripsodes cinereus	(CURTIS, 1834)	34.3	0.422
Ep	Oligoneuriella rhenana	(IMHOFF, 1852)	33.3	0.041
Bi	Sphaerium sp.		33.3	0.419
Di	Antocha sp.		30.7	0.464
Ep	Baetis alpinus-Gr.		25.0	0.101
Ga	Theodoxus fluviatilis	(LINNAEUS, 1758)	25.0	0.104
Ep	Electrogena sp.		21.2	0.218
Tc	Oecetis notata	(RAMBUR, 1842)	19.5	0.254
Co	Orectochilus villosus Ad.	(MÜLLER, 1776)	16.7	0.197
Ep	Ecdyonurus insignis	(EATON, 1870)	16.7	0.219
Ep	Baetis liebenauae	KEFFERMÜLLER, 1974	16.7	0.224
Co	Riolus sp. Lv.		16.7	0.225
Ep	Baetis vardarensis	IKONOMOV, 1962	16.7	0.237
Tc	Lasiocephala basalis	(KOLENATI, 1848)	16.7	0.241
Od	Calopteryx splendens	(HARRIS, 1782)	14.7	0.334
Di	Tipula maxima-Gr.		12.6	0.331
Co	Stenelmis canaliculata Ad.	(GYLLENHÅL, 1808)	12.2	0.366
Tc	Hydropsyche contubernalis	McLACHLAN, 1865	8.3	0.467
He	Nepa cinerea	LINNAEUS, 1758	8.3	0.469
Co	Esolus pygmaeus Ad.	(MÜLLER, 1806)	8.3	0.476
Co	Normandia nitens Ad.	(MÜLLER, 1817)	8.3	0.476
Cr	Proasellus coxalis	(DOLLFUS, 1892)	8.3	0.476
Ep	Torleya major	KLAPÁLEK, 1905	8.3	0.476
Ep	Heptagenia longicauda	(STEPHENS, 1836)	8.3	0.478
Ep	Rhithrogena beskidensis	ALBA-TERCEDOR & SOWA, 1987	8.3	0.478

Group	Taxon	Author	IV	p
Tc	Lype reducta	(HAGEN, 1868)	8.3	0.478
Ne	Gordius aquaticus	(LINNAEUS, 1758)	8.3	0.490
Di	Atrichops crassipes	(MEIGEN, 1820)	8.3	0.492
Di	Limnophora sp.		8.3	0.492
Tc	Goera pilosa	(FABRICIUS, 1775)	7.9	0.866

1.4.5 Discussion

The size of the catchment was the main classification factor for Sommerhäuser & Pottgiesser (2004) to define the two German stream types 9 (mid-sized streams in lower mountainous areas) and 9.2 (large streams in lower mountainous areas) *a priori*. They suggested that a catchment size larger than 1000 km^2 supports a different faunal assemblage than smaller catchments.

Their ideas are underpinned by the results of the cluster analysis (see Chapter 1.2) and the performed key indicator analysis. The predefined stream types can thus be accepted for the investigated sampling sites, with the exception of the Eder at Niedermöllrich (for an explanation see Chapter 1.2.4).

The overall difference in the faunal composition of the two stream types is displayed by the taxonomic resolution diagrams (e.g. Figure 10). Further details express the key indicator tables (Table 8 and Table 9).

The major differences in the morphology of the streams (e.g. altitude, slope, channel width or shading; see Chapter 1.4.2) cause gradients in current, temperature or algae production, resulting in a clearly distinguishable fauna. A well developed stonefly assemblage of *Isoperla* sp., *Leuctra geniculata* and the key species *Perla burmeisteriana* determine the biocoenosis of mid-sized mountain streams (stream type 9). The mayfly community of this stream type is dominated by different *Ecdyonurus* and *Baetis* species (e.g. *B. lutheri*). Another mayfly is *Epeorus sylvicola*, which needs high current velocities like the midge genus *Prosimulium*. In contrast, *Heptagenia sulphurea* was only found in type 9.2 streams and socializes with other potamophilic mayflies like *Oligoneurhiella rhenana* and *Potamanthus luteus*. In the order Trichoptera, a zonal gradient in the macrobenthic fauna is evident, too: *Anomalopterygella chauviniana*, *Allogamus auricollis*, *Sericostoma* sp. (S. *flavicorne/personatum*) and the genus *Rhyacophila* represent caddisflies from the mid-sized streams. Even within a family changes are obvious; the genus *Micrasema* (*M. minimum*, *M. longulum* and *M. setiferum*) of the family Brachycentridae is followed by *Brachycentrus subnubilus*, a key caddisfly of the large streams. The genus *Athripsodes* (Leptoceridae) is more abundant in the large streams as well as *Psychomyia pusilla* (Psychomyidae), *Cheumatopsyche lepida* (Hydropsychidae) and *Lepidostoma hirtum* (Lepidostomatidae).

In the order Coleoptera *Hydraena dentipes*, *H. gracilis*, *H. reyi* and *Elmis maugetii* inhabit the mid-sized streams, being replaced downstream by *Stenelmis canaliculata, Esolus pygmaeus* and *Limnius volckmari*. The latter one is also present in mid-sized streams but the frequency and abundance is higher in the large streams.

The Crustacean fauna displays high abundances of *Asellus aquaticus* and *Gammarus roeseli* in the large streams and in contrast to the mid-sized streams low numbers of *Gammarus pulex*. Other key potamophilic species are *Theoduxus fluviatilis* (Gastropoda) and *Aphelocheirus aestivalis* (Heteroptera). For the leeches a change in the zonation can be seen from species of the genus *Erpobdella* upstream to the genus *Piscicola* downstream. *Bithynia tentaculata* (Gastropoda), *Asellus aquaticus* (Crustacea) and *Theodoxus fluviatilis* display a change in the river continuum (Vannote et al. 1980), as well as a low pollution load (indicated by bad saprobic values in the German saprobic index; Rolauffs et al. 2003), which is present in the large streams. The grazers gain more percentages of the faunal assemblage in comparison to the upstream reaches. The overall stream width of the type 9.2 streams is larger than in the stream type 9 sites thus, shading by riparian trees is reduced and the influence of the sun leads to an increased algae development ultimately supporting grazer activities.

Most of these zonation preferences of the species have already been considered in Moog (1995) and Schmedtje & Colling (1996) by their classification systems for biocoenotic regions. Both authors developed an index using the zonal preferences of species to calculate from given taxa lists the affiliation to a stream zone. These preferences can also be used to detect changes (or degradations) in the faunal composition: if e.g. a stream is straightened then the current velocities are faster than natural at that site and more rheophilous species occur, which normally inhabit upstream (rhithral) sections.

Therefore, longitudinal changes in the invertebrate community fauna could indicate a stream type but also in selected cases anthropogenical (hydromorphological) alteration.

2 Development of an assessment system for mid-sized streams in lower mountainous areas of Germany

Abstract

A new Multimetric Index for stream assessment was developed, which mainly focuses on the impact of hydromorphological degradation on the macroinvertebrate fauna. The index was developed for mid-sized streams in lower mountainous areas. Sites representing different stages of hydromorphological degradation were investigated; the macroinvertebrate fauna of each site was sampled twice in the year 2000 (20 sites, 40 samples altogether). In addition, more than 200 parameters describing the hydromorphology of the sites have been recorded.

The development process of the assessment system included (1) the generation of a new index ("German Fauna Index"), (2) the selection of faunal metrics, which correlate to hydromorphological degradation and (3) the combination of the selected metrics into a Multimetric Index. To correlate faunal metrics and hydromorphological degradation, a "Structure Index" describing the alteration of stream morphology was generated. A correlation matrix of the selected metrics and the "Structure Index" is presented.

The "German Fauna Index" is based on taxa, which predominantly occur at sites of a certain morphological degradation class. The selection process of taxa included in the new index was firstly based on data sampled in this study and secondly supplemented by literature data.

The process of metric selection and validation is described in detail, including a correlation matrix of the metrics and a validation of the metrics with data on additional sampling sites.

2.1 A new method for assessing the impact of hydromorphological degradation on the macroinvertebrate fauna

2.1.1 Introduction

The use of macroinvertebrates in stream assessment has mainly focussed on indicating water quality, in particular the impact of organic pollution or acidification. The deterioration of macroinvertebrate communities caused by organic pollution can be measured employing a wide variety of metrics, amongst others Saprobic indices (Zelinka & Marvan 1961) or the BMWP and ASPT scores (Armitage et al. 1983). Other approaches aim to assess the general degradation of the macroinvertebrate fauna caused by a multitude of influences, such as land use in the catchment, hydromorphology and water quality. This can either be done with metrics, such as the Danish Stream Fauna Index (Skriver et al. 2000), multimetric systems (Karr & Chu 1999) or through prediction systems, that measure the distance of the observed fauna to an expected reference community (Wright et al. 1993; Kokes et al. 2001). Most of these systems do not aim to separate the impact of different stressors. Only recently multimetric systems with stressor-specific approaches have been developed for many European river types (Brabec et al. 2004; Buffagni et al. 2004; Ofenböck et al. 2004; Sandin et al. 2004).

In Germany, stream assessment using macroinvertebrates usually concentrated through the German Saprobic System (DEV 1992) on detecting organic pollution. However, water quality improved greatly in the last decades and at present, in mountainous regions (State Hesse) 81.0 % of stream and river sections are not or only slightly polluted ("oligosaprob" or "beta-mesosaprob") (http://www.mulf.hessen.de/umwelt/wasser). In contrast, the hydro-morphology of German streams is in a poor condition. A nationwide survey based on a method described by LAWA (2001), which is coherent to the respective CEN standard, revealed that in mountainous regions of the State Hesse only 19.7 % of the streams were classified in the best three (out of seven) morphological quality categories, while 64.1 % of the streams belonged to the lowest three classes (Hessisches Ministerium für Umwelt, Landwirtschaft und Forsten 2000). In lowland catchments of North Rhine-Westphalia only 2 % of the stream sections were reported to be in a good (highest two out of seven classes) and 54 % in a poor hydromorphological condition (lowest two out of seven classes;

http://www.umweltamt.org/aktuell/dateien/s_guete1.pdf and unpublished data released by StUA Münster 2001). The situation is similar in countries adjacent to these German states. In the Netherlands, only approximately 4 % of the streams have a near-natural morphology and hydrology (Verdonschot & Nijboer 2002), and in Denmark only 2 % are more or less natural (Brookes 1987).

For decades, most attempts to "rehabilitate" Central European streams and rivers aimed for an improvement of water quality. Now it becomes more and more apparent, that physical habitat degradation is the most important remaining threat to aquatic and riparian biodiversity. Straightening of streams, dam construction, the disconnection of the stream from its floodplain and alteration of riparian structure and vegetation led to a loss of several habitat types and associated species (Zwick 1992).

The EU Water Framework Directive, which serves as a guideline for future stream assessment methods throughout Europe, defines the direct assessment of hydromorphology only as an additional measure, while the main focus lies on biotic indicators. Biotic indicators should reflect the impact of all stressors; in Central Europe, hydromorphology is likely to be one of the most important. Ultimately, this poses an important question: to what degree does the macroinvertebrate fauna reflect the hydromorphological conditions of a site or reach? Many macroinvertebrate species predominantly occur in certain microhabitats and need certain morphological structures for oviposition, pupation and a habitat for the terrestrial adult stages (Resh & Rosenberg 1993; Merritt & Cummins 1996; Hoffmann & Hering 2000). Thus, the macroinvertebrate fauna of a stream should, amongst others, be the result of the structural integrity of the site and the catchment.

The present study focuses on interactions of the macroinvertebrate fauna and the hydromorphological quality on the site scale. The underlying questions of the study can be addressed as follows:

- Is there a correlation between the hydromorphological quality and patterns (occurrence/abundance of taxa; metrics) of the macroinvertebrate fauna?
- If yes, which patterns are best suited to assess the impact of hydromorphological degradation on the fauna?

2.1.2 Materials and methods

Site selection and sampling

A stream type, which is located in lower mountainous areas of Germany (ecoregion 8 and 9 according to Illies 1978) was investigated during the course of this study (Figure 22). The altitude of the sampling sites ranged between 200 and 500 m above sea level on a siliceous geology, from which gravel derives as the dominant substrate. The catchment area of the sampling sites was restricted to 100 to 1000 km^2. Thus, all sites belonged to the stream type 9 of the recent German stream typology (Sommerhäuser & Pottgiesser 2004).

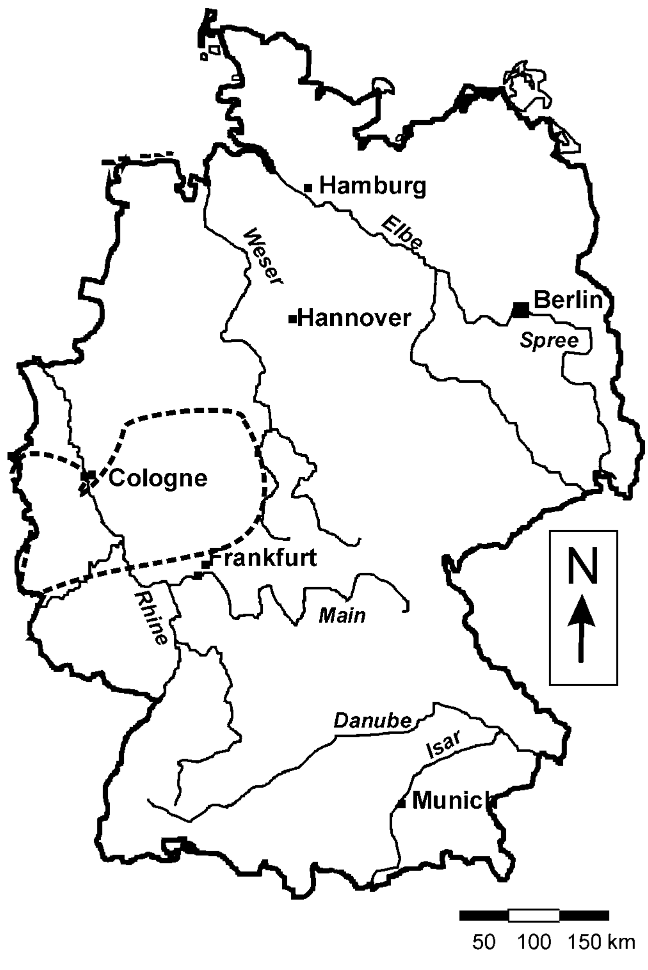


Figure 22. Distribution of the sampling area of the mid-sized mountain streams in Germany. The dotted line marks the boundary of the study area.

20 sampling sites were selected (Table 11) spreading over three Federal States and a total area of approximately 30,000 km^2. The rationale behind the selection process was to cover a gradient from near-natural sites (e.g. Figure 25, Figure 26) to heavily degraded sections (Figure 24). The degradation of the sites was mainly caused by hydromorphological

alterations, while the level of organic pollution was low or moderate in all cases according to official sources. The geological formation should also not distinguish between sites thus, physico-chemical gradients were relatively similar (Appendix 5). With the help of simple parameters such as number of logs or straightening, morphological degradation classes were preliminary assigned to all sites ("pre-classification") (Table 11). Consequently, sampling sites represented the present situation of mountain streams in Germany: low to moderate pollution and different degrees of hydromorphological degradation.

Table 10. Sampling dates and allocation of samples within the stream reach of the mid-sized streams in lower mountainous areas of Germany; for site codes compare Table 11. (the last number of the site code represents the season: 1 = spring, 2 = summer)

Site code	Spring sample	Pool	Riffle	Site code	Summer sample	Pool	Riffle
D0500011	13.03.2000	9	11	D0500012	26.06.2000	14	6
D0500021	13.03.2000	5	15	D0500022	26.06.2000	10	10
D0500031	14.03.2000	0	20	D0500032	19.07.2000	0	20
D0500041	14.03.2000	0	20	D0500042	19.07.2000	0	20
D0500051	22.03.2000	12	8	D0500052	20.07.2000	6	14
D0500061	22.03.2000	16	4	D0500062	19.07.2000	18	2
D0500071	22.03.2000	12	8	D0500072	20.07.2000	10	10
D0500081	28.03.2000	6	14	D0500082	20.07.2000	6	14
D0500091	14.03.2000	8	12	D0500092	19.07.2000	8	12
D0500101	15.03.2000	0	20	D0500102	04.07.2000	0	20
D0500111	15.03.2000	20	0	D0500112	04.07.2000	20	0
D0500121	27.03.2000	0	20	D0500122	06.07.2000	0	20
D0500131	27.03.2000	0	20	D0500132	06.07.2000	20	0
D0500141	27.03.2000	0	20	D0500142	29.06.2000	8	12
D0500151	29.03.2000	5	15	D0500152	30.06.2000	10	10
D0500161	27.03.2000	10	10	D0500162	29.06.2000	10	10
D0500171	29.03.2000	4	16	D0500172	29.06.2000	10	10
D0500181	29.03.2000	0	20	D0500182	29.06.2000	10	10
D0500191	02.03.2001	20	0	D0500192	04.07.2000	20	0
D0500201	21.03.2001	4	16	D0500202	20.07.2000	4	16

A total of 40 samples were taken in spring (March 2000 or 2001) and summer (June/July 2000) using a multi-habitat-sampling technique (Table 10; Hering et al. 2004). Subsequent sample processing included a sieving process separating the samples into a coarse (> 2000 µm) and a fine fraction (> 500 µm). Further analyses were limited to the coarse fraction.

Table 11. Characterisation of the sampling sites of the mid-sized streams in lower mountainous areas of Germany; the site code will be used in the following tables as an abbreviation for the complete stream and site name. (Preclassification: 1 = high, 5 = bad; Federal State: NW = North Rhine-Westphalia, RP = Rhineland-Palatinate, HE = Hesse; Ecoregion: 8 = Western Sub-alpine Mountains, 9 = Central Sub-alpine Mountains)

Site code	Stream name	Site name	Preclas-sification	Federal State	Map no.	Longitude	Latitude	Eco-region	Stream system	Altitude [m]	Distance to source [km]	Catchment area [km²]
D050001	Rur	Dedenborn	3	NW	5404 Schleiden	06,20,42	50,34,35	8	Maas, Rhine	315	33	185
D050002	Rur	Wiselsley	1	NW	5403 Monschau	06,17,07	50,33,40	8	Maas, Rhine	360	24	154
D050003	Kyll	Gerolstein	4	RP	5705 Gerolstein	06,38,23	50,13,14	8	Moselle, Rhine	350	45	301
D050004	Kyll	Densborn	3	RP	5805 Mürlenbach	06,36,02	50,06,55	8	Moselle, Rhine	305	60	472
D050005	Kyll	Erdorf	2	RP	5905 Kyllburg	06,34,02	50,00,38	8	Moselle, Rhine	245	87	572
D050006	Prüm	Waxweiler	4	RP	5904 Waxweiler	06,22,08	50,05,18	8	Moselle, Rhine	315	39	287
D050007	Our	Auel	2	RP	5703 Bleialf	06,10,32	50,13,07	8	Moselle, Rhine	360	33	294
D050008	Nims	Birtlingen	1	RP	6004 Oberweiss	06,29,04	49,56,52	8	Moselle, Rhine	245	44	222
D050009	Ahr	Altenahr	2	NW	5407 Altenahr	06,59,44	50,30,27	8	Rhine	156	54	750
D050010	Lenne	Lennestadt	4	NW	4814 Lennestadt	08,04,35	51,06,31	9	Ruhr, Rhine	280	41	190
D050011	Lenne	Finnentrop	5	NW	4813 Attendorn	07,57,56	51,10,42	9	Ruhr, Rhine	235	55	826
D050012	Lahn	Ludwigslust	3	NW	5017 Biedenkopf	08,30,44	50,54,59	9	Rhine	275	27	287
D050013	Lahn	Bad Laasphe	4	NW	5016 Bad Laasphe	08,26,18	50,55,41	9	Rhine	305	20	152
D050014	Nuhne	Neukirchen	3	HE	4818 Medebach	08,44,10	51,07,22	9	Eder, Weser	310	25	134
D050015	Eder	Röddenau	2	HE	4918 Frankenberg	08,44,22	51,01,56	9	Weser	280	78	524
D050016	Eder	Beddelhausen	3	NW	4915 Bad Berleburg	08,29,33	50,59,55	9	Weser	350	45	359
D050017	Orke	Dalwigksthal	2	HE	4818 Medebach	08,49,13	51,09,04	9	Eder, Weser	295	28	275
D050018	Orke	Reckenberg	2	HE	4819 Fürstenberg	08,50,06	51,09,15	9	Eder, Weser	280	31	289
D050019	Lenne	Werdohl	5	NW	4711 Altena	07,47,52	51,15,26	9	Ruhr, Rhine	200	71	1048
D050020	Prüm	Wüstung Beifels	2	RP	5904 Waxweiler	06,25,23	50,03,00	8	Moselle, Rhine	280	48	327

Figure 23. Anthropogenic alteration and fixation of a mountain stream.

Figure 24. Result of an anthropogenic alteration: Straightened, mid-sized mountain stream (Lenne) with reinforced banks.

Figure 25. Anabranching, near-natural, mid-sized mountain stream (Orke).

Figure 26. Near-natural, shallow, mid-sized mountain stream (Prüm).

Identification was carried out mainly to species level, with the exceptions of Oligochaeta (usually family level), Chironomidae (mixed level ranging from species to tribe), Simuliidae and Limoniidae (both genus level), and Brachycera (family level). A maximum of 78 taxa was found in spring in the Eder at Röddenau (D0500151) and in summer in the Orke at Dalwigksthal (D0500172). The abundance was highest in the summer sample of the Kyll at Erdorf (D0500051) with 5494.4 Ind/m^2. Lowest numbers are identified in the summer sample of the Lenne at Finnentrop (D0500112; 18 taxa) and the spring sample of the Lahn at Bad Laasphe (D0500131; 122.4 Ind/m^2) (Appendix 6 and Appendix 7).

The Structure Index

Approximately 200 parameters describing morphology, chemistry, hydrology and catchment characteristics were recorded using a standardised site protocol (Feld 2004; Hering et al. 2004). These data were used to derive a hydromorphological classification of each site as a value ranging from 0 to 100 ("Structure Index"). The German hydromorphological survey protocol ("Gewässerstrukturgütekartierung"; LAWA 2001) was not applied, because the parameters are recorded in a general way thus, it is not assigned to the special hydromorphological problems of mid-sized stream in lower mountainous areas. The "Structure Index" was also used to describe "Structural Quality Classes" ranging from 5 (high hydromorphological status) to 1 (bad hydromorphological status). Different parameters of the site protocol have been selected for the "Structure Index", which discriminate between the unstressed and stressed sampling sites and, which are likely to affect the benthic invertebrate fauna (Table 12). The selected parameters were individually scored from 0 (degraded) to 100 (reference). For calculating the final index value the scores of the individual parameters were averaged. The scores were assigned to the sampling sites not to the sampling dates to emphasize the overall hydromorphological degradation of the site not a single day situation.

Table 12. Hydromorphological parameters used to define the "Structure Index".

Parameter	Scoring	Relevance
Channel form	Positiv scores for: sinuate or anabranching Negativ scores for: constrained (artificial)	Under near-natural conditions the channel form varies between sinuate single thread channels and anabranching multi-thread channels; under present anthropogenically altered conditions the channel is mainly constrained

Parameter	Scoring	Relevance
Relation of width of the channel to width of the floodplain	Ratio of mean season channel width to floodplain width	Under near-natural conditions the stream uses the entire width of the floodplain; under present anthropogenically altered conditions the stream is forced into a small channel within the floodplain
Discharge patterns	Ratio of mean annual discharge to mean season channel width	Under near-natural conditions the stream width rises with the mean annual discharge; under present anthropogenically altered conditions the ratio is not continuously adapted to the discharge
Current (flow) diversity	Range of current velocity of both seasons (Appendix 4)	Under near-natural conditions there is a high current diversity with dead water zones as well as high current zones in the stream; under present anthropogenically altered conditions (e.g. straightening) the current becomes uniform
Share of woody debris [%]	Number of logs	Under near-natural conditions woody debris is present in high ratios; under present anthropogenically altered conditions this dead wood is removed
Positive and negative channel patterns	Positiv scores for: backwaters in the floodplain Negativ scores for: stagnation, straightening, impoundments and deepcutting	Under near-natural conditions there are different stages of backwaters in the floodplain, the channel is at least sinuate and the stream is not incised into the floodplain; under present anthropogenically altered conditions land use in the floodplain is secured by straightening and impoundments, which causes deepcutting; the backwaters are filled up for better cultivation
Presence of migration barriers	Negativ scores for: (artificial) dams	Under near-natural conditions there are no dams, which cause (total) stagnation and trapping of sediment

Selection and development of metrics

Approximately 200 metrics (listed in Hering et al. 2004) were derived from the fauna data set and tested to identify calculation methods, with a close correlation to the "Structure Index". The selection of metrics suitable to assess the impact of hydromorphological degradation on the macroinvertebrate fauna was based on the following criteria:

(1) The metric must decrease or increase with increasing "Structure Index" (tested by linear correlation).

(2) All criteria defined by the EU Water Framework Directive for the assessment of the benthic invertebrate fauna (taxonomic composition, abundance, ratio sensitive/insensitive taxa, diversity) should be covered by the selected metrics.

(3) There should be a theoretical rationale why the metric changes with hydromorphological degradation.
(4) The metrics should not be redundant (tested by linear correlation of candidate metric results).

In addition, a new metric was developed ("German Fauna Index"), based on a stream type-specific list of indicator taxa. Although the selection of indicator taxa necessarily included a certain degree of expert judgement, the following criteria were defined to keep the selection process as transparent as possible:

(1) The occurrence and/or abundance of an indicator taxon correlates, positively or negatively, with the "Structure Index"; thus, the taxon shows a preference for either reference/good sites or hydromorphologically degraded sites. Evaluation of the data was performed with the PC program IndVal (Dufrêne & Legendre 1997) (details in Appendix 3). This criterion was used for both, positive and negative indicator taxa.
(2) Based on literature data, the taxon shows a preference for a certain habitat, either typical for the reference situation (e.g. coarse wood, lentic zones in the shore area) or for degraded sections (e.g. stagnant zones in the headwaters of dams). The literature data used are partly empirical and partly experimental (references are given in Appendix 3). The near-natural habitat composition was taken into account in this step (derived from LUA NRW 1999a, 1999b, 2000, 2001). This criterion was used for both, positive and negative indicator taxa.
(3) The taxon historically occured in the stream type. These taxa received a positive value.
(4) Under near-natural conditions, the taxon shows a clear preference for the stream type. These taxa were mainly taken from LUA NRW (1999a, 1999b, 2000, 2001) and received positive values.

Four different scores (+2, +1, −1, −2) were assigned to the selected indicator taxa. The "German Fauna Index" is then calculated as:

$$\text{German Fauna Index} = \frac{\sum_{i}^{N} sc_i \cdot a_i}{\sum_{i}^{N} a_i}$$

(N = total number of indicator taxa; i = number of indicator taxa; sc_i = score of the i^{th} taxon; a_i = abundance class of the i^{th} taxon; abundance class defined as: 1 – 3 ind. = class 1; 4 - 10 ind. = class 2; 11 – 30 ind. = class 3; 31 – 100 ind. = class 4; 101 – 300 ind. = class 5; 301 - 1000 ind. = class 6; > 1000 ind. = class 7)

Ecological Quality Classes and Multimetric Index

For each selected metric, Ecological Quality Classes were defined ranging from 5 (high status) to 1 (bad status). In a first step, this scoring system was solely based on the samples taken throughout this study, which supposedly covered all stages of degradation. As a general rule, the class boundaries were taken from the index values achieved in a certain Structural Quality Class (defined by the "Structure Index"): if 25 % of the investigated sites were assigned to structural class 5, then the 25 % highest metric values were also assigned to quality class 5.
The scores of the individual metrics were summarised to a Multimetric Index called "Ecological Quality Index using Macroinvertebrates" (EQI_M), which ranges from 5 (high status) to 1 (bad status). The EQI_M is calculated as the average score of all metrics included; a weighting factor ensures that the "German Fauna Index" contributes 50 % to the Multimetric Index.
The validity of the assessment method was tested with data taken from other studies and, which have been collected with comparable sampling methods. For the mid-sized mountain streams, data on 32 sampling sites from Frenz & Hering (1999) and LUA NRW (2001) were used.

2.1.3 Results

The "Structure Index"

The individual scores of the sampling sites for the "Structure Index" are ordered according to their values (Figure 27). Highest scores are found for the Prüm at Wüstung Beifels (D050020) and the Rur at Wiselsley (D050002; both above 70). The range of scores ends with two sites at the river Lenne, which are on the one hand the headwater of a dam (D050011) and on the other hand a straightened outflow of a hydropower station (D050019). The results reflect the present day situation. Even the best sites are far from near-natural hydromorphology and thus, the scores are not higher than 72. The lower range of scores is explainable, too. There are at least some features, which can get positive scores in the degraded sites (e.g. by damming the incising of the stream is stopped and often the complete floodplain inundated).

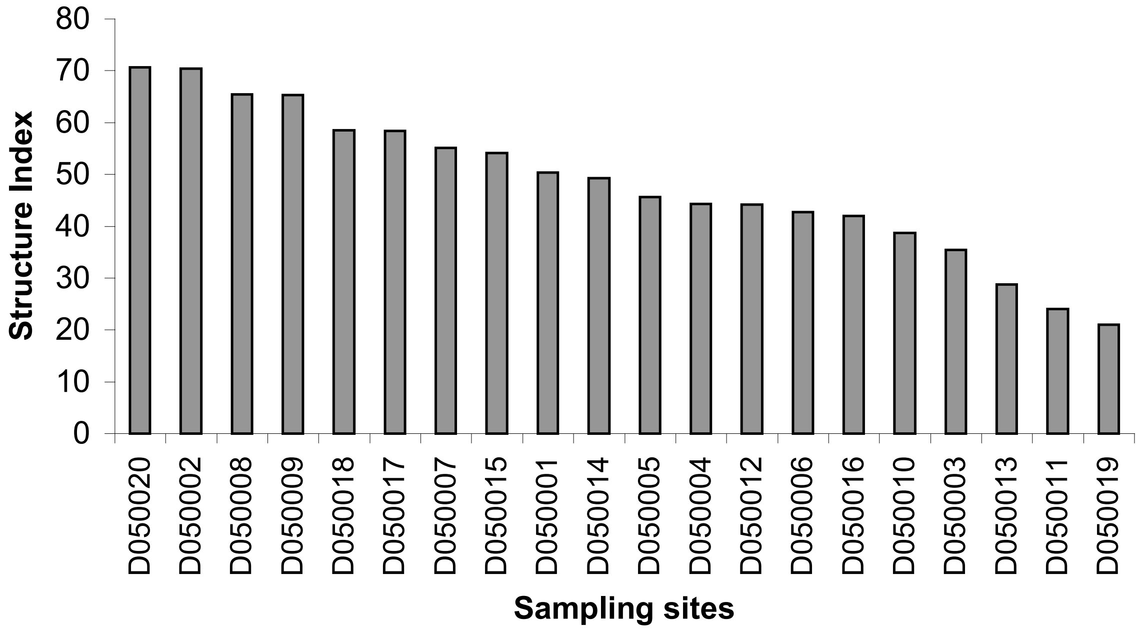


Figure 27. Scores of the sampling sites for the "Structure Index" in hierarchical order; for site codes compare Table 11.

The "German Fauna Index"

155 taxa have been identified as indicators for the mid-sized streams in lower mountainous areas of Germany. The negative taxa (53) are only approximately half the number of the positive indicators (102) (Appendix 3). This is due to a wide variety of habitats (substrate combinations with current situations), which occur in reference situations (LUA NRW 1999b, 2001) and consequently support a large number of species, which are adapted to the special habitats, e.g. taxa from lentic zones near the shoreline (e.g. *Siphlonurus* sp.), taxa that indicate high current velocities (e.g. *Oligoneuriella rhenana*) or those preferring scarce habitats (*Ephemera danica* in sandy patches). Negative scores are assigned to taxa, which indicate stagnant situations (e.g. the genera *Haliplus, Nebrioporus* and *Mystacides* in reservoirs), prefer rhithral sections (e.g. *Esolus angustatus*) thus, indicating straightening ("rhithralisation") or if particular species occur in large numbers (e.g. the genera *Erpobdella* or *Sialis*) then a degradation can be delineated.

Rationale of metric selection

Four metrics, aiming to indicate additional characteristics of mid-sized mountain streams under reference conditions and correlated to the hydromorphological quality of the sites (Figure 28), were selected to supplement the "German Fauna Index":

(1) Shannon-Wiener-Diversity (Shannon & Weaver 1949);

(2) Number of Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Bivalvia and Odonata (EPTCBO) taxa: although most mid-sized mountain streams are dominated by homogeneous stony substrates, they were formerly characterised by a high substrate diversity (LUA NRW 2001, Ehlert et al. 2002), likely resulting in both, a higher number of taxa and higher species diversity.

(3) Percentage of xylophagous taxa, shredders, active filter feeders and passive filter feeders ("Feeding Type Index"): under reference conditions, the catchment is completely covered by natural woody vegetation and the river contains a large amount of woody debris (Hering et al. 2000). This debris traps other coarse organic material, which results in a reference invertebrate fauna with a high percentage of xylophagous and shredder taxa, supplemented by filter feeders dependent on the fine particulate organic matter (FPOM) generated by the shredders.

(4) Percentage of akal (gravel), lithal (stone) and psammal (sand) preferences ("Habitat Index"): under reference conditions, the stream-bed is dominated by stony and gravelly substrates and additionally sandy patches are frequently found in lentic zones. Therefore, the reference invertebrate fauna is dominated by taxa with these habitat preferences.

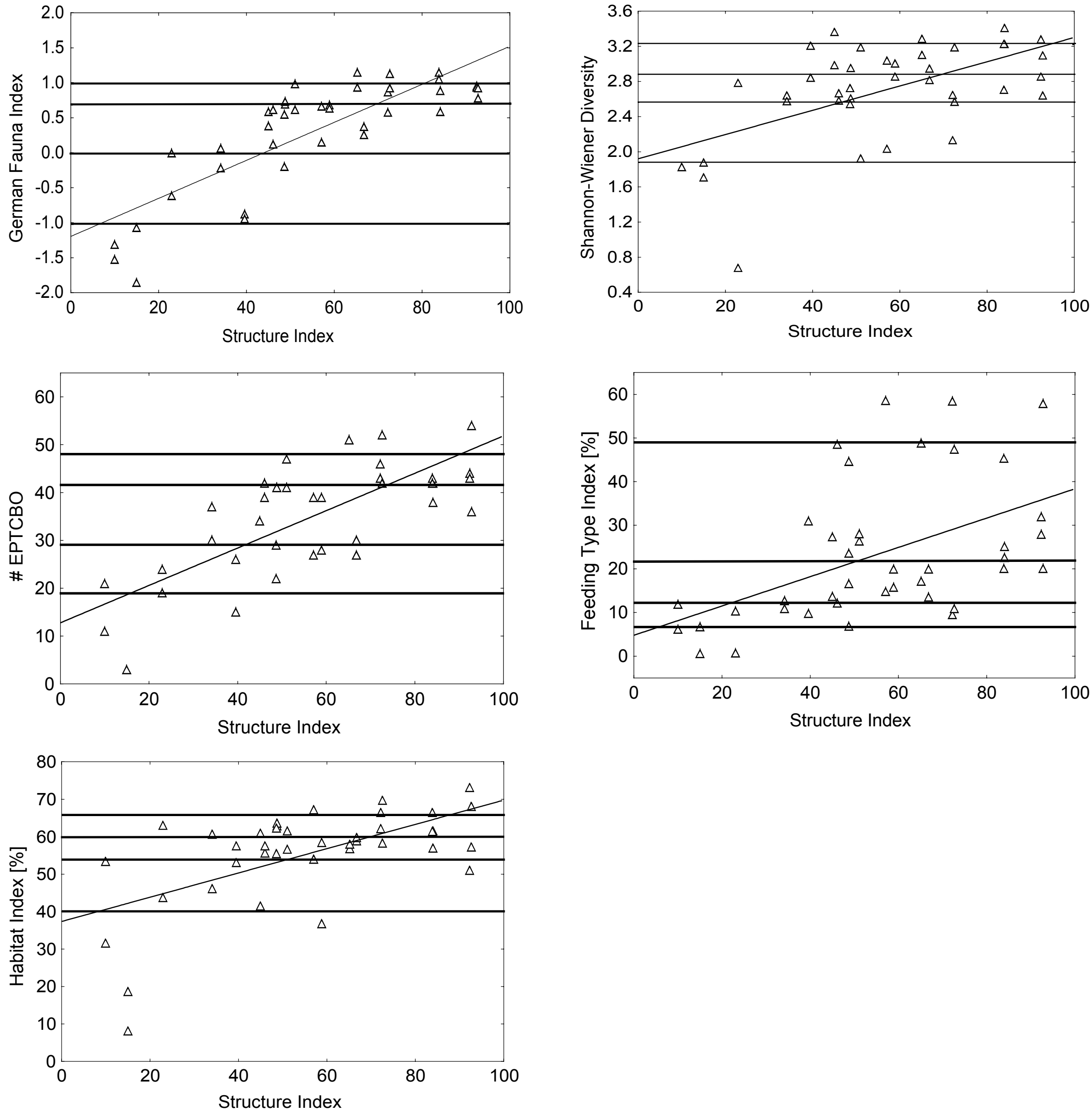


Figure 28. Linear regression of the individual metrics and the "Structure Index" for mid-sized mountain streams, including the boundaries of the Ecological Quality Classes: "German Fauna Index" (r^2 = 0.81), Shannon-Wiener-Diversity (r^2 = 0.34), number of Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Odonata and Bivalvia taxa (r^2 = 0.54), [%] xylophagous taxa, shredder, active filter feeders and passive filter feeders ("Feeding Type Index") (r^2 = 0.24), [%] akal, lithal and psammal preferences ("Habitat Index") (r^2 = 0.35).

The "German Fauna Index" and the additional four metrics cover all criteria required for the assessment of the benthic invertebrate fauna according to the EU Water Framework Directive (Table 13). They are only weakly correlated with each other, with the exception of the "Habitat Index" and number of EPTCBO taxa (r^2 = 0.51; Table 14).

Table 13. Metrics included into the Multimetric System. Criteria of the EU Water Framework Directive for the assessment with benthic invertebrates addressed by the metric: abd = abundance; div = diversity; rat = ratio of sensitive and robust taxa; tax = taxonomic composition; r^2, p: Linear correlation of the metric (dependent variable) and the "Structure Index" describing the morphological degradation (independent variable); linear regression.

Metric	Criterion	r^2	p
German Fauna Index	tax; rat	0.67	< 0.001
Number of Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Bivalvia and Odonata taxa	tax	0.54	< 0.001
[%] Xylophagous taxa, shredder, active filter feeders and passive filter feeders	abd; rat	0.24	< 0.01
[%] Akal, lithal and psammal preferences	abd; rat	0.35	< 0.001
Shannon-Wiener-Diversity	div	0.34	< 0.001

Table 14. Correlation matrix of the individual metrics included into the Multimetric System, the Ecological Quality Index (EQI_M) and the German Saprobic Index (DIN 38410); r^2 values, linear correlation. # EPTCBO = number of Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Bivalvia and Odonata taxa; "Feeding Type Index" = [%] xylophagous taxa, shredder, active filter feeders and passive filter feeders; "Habitat Index" = [%] akal, lithal and psammal preferences; DIN 38 410 = German Saprobic System; Ecological Quality Index (EQI_M) = composed of "German Fauna Index" (50 %), # EPTCBO, Shannon-Wiener-Diversity, "Feeding Type Index", "Habitat Index".

	# EPTCBO	Shannon-Wiener-Div.	Feeding Type Index	Habitat Index	German Fauna Index	DIN 38 410	EQI_M
# EPTCBO							
Shannon-Wiener-Div.	0.28						
Feeding Type Index	0.13	0.02					
Habitat Index	0.51	0.07	0.18				
German Fauna Index	0.77	0.36	0.21	0.42			
DIN 38 410	0.43	0.28	0.21	0.45	0.65		
EQI_M	0.80	0.38	0.28	0.48	0.88	0.54	

Although the correlation with the "German Fauna Index" is usually stronger, they are included into the Ecological Quality Index (EQI_M) for stabilisation in case only a small number of indicator taxa of the "German Fauna Index" are found in a particular sample. The resulting EQI_M shows a clear correlation to the hydromorphological quality of the sites (Figure 29).

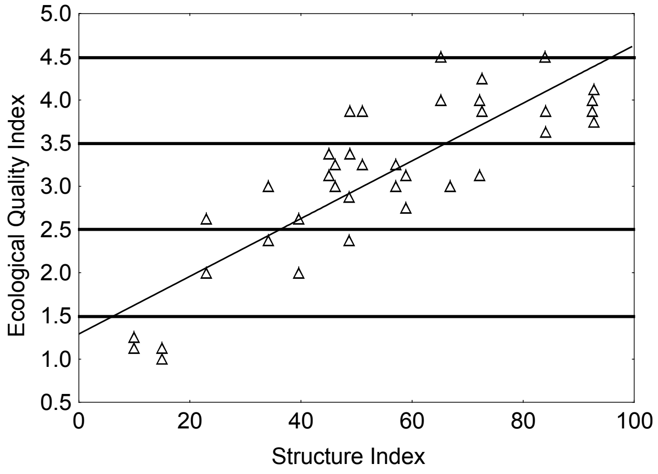


Figure 29. Linear regression of the Ecological Quality Index (EQI_M) and the "Structure Index" ($r^2 = 0.67$).

Considering data on additional sampling sites the EQI_M shows only "poor" or "bad" values for sections of the river Lenne, which are heavily degraded due to stagnant conditions or residual flow (Figure 30), sections of several rivers in North Rhine-Westphalia, with a "moderate" morphological evaluation, were assessed as "poor", "moderate" or "good" using the EQI_M (Figure 30).

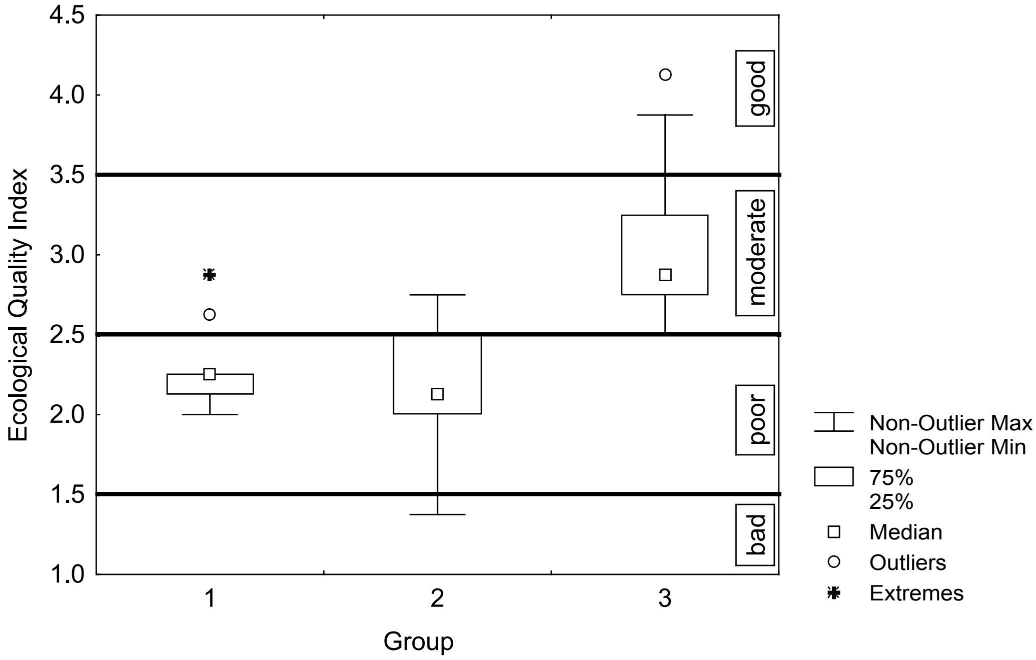


Figure 30. Application of the Ecological Quality Index (EQI_M) to additional sampling sites. Group 1: Heavily degraded sections of the river Lenne (residual flow sections and stagnant sections) (data from Frenz & Hering 1999). Group 2: Sections of the river Lenne with a degraded hydromorphology, but not dammed or effected by residual flow (data from Frenz & Hering 1999). Group 3: Sections of several rivers in North Rhine-Westphalia; the morphology covers a wide range but was mainly estimated to be in a "moderate" condition (data from LUA 2001).

The results of the "German Fauna Index" are strongly correlated with the results of the "Structure Index" (r^2 = 0.67; Table 15). The correlation of the metrics selected with the "Structure Index" is usually weaker (Table 13). However, the correlation of the individual metrics with each other is generally weak (Table 14), so that they indicate additional characteristics of the community. The correlation of the Ecological Quality Index and the hydromorphological quality is similar to the correlation of the "German Fauna Index" and the "Structure Index" (Table 15).

Table 15. Correlation of the "German Fauna Index" and the Ecological Quality Index (EQI_M), respectively and the "Structure Index" describing the morphological degradation; linear regression.

German Fauna Index		Ecological Quality Index	
r^2	p	r^2	p
0.67	< 0.001	0.72	< 0.001

2.1.4 Discussion

Stressor-specific indices and assessment systems have been generated for organic pollution (amongst others de Pauw & Vanhooren 1983; AFNOR 1985; Alba-Tercedor & Sanchez-Ortega 1988; DEV 1992; Moog et al. 1999), acidification (Henrikson & Medin 1986; Rutt et al. 1990; Braukmann 2000) or the impact of heavy metals (Paasavirta 1990; Reynoldson et al. 1997). There are two reasons for stressor-specific assessment methods. Firstly, individual taxa may not be equally sensitive to all types of stressors (Chessman & McEnvoy 1998) thus, offering the opportunity to discriminate between different impairments. Secondly, it is often important for general monitoring programmes to have information about the cause of a possible degradation in addition to the overall Ecological Quality.

At present, the main stressor affecting Central European streams appears to be hydromorphological degradation and a multitude of methods have been developed to assess river morphology with abiotic protocols. A recent review (Birk & Hering 2002) lists 21 protocols for hydromorphological assessment and classification, which are applied or are under development in several European countries (see also Maddock 1999). According to the EU Water Framework Directive the direct assessment of hydromorphology can only be a supplementary measure for stream assessment in Europe. Therefore, there is a strong demand for evaluation methods based on the biotic communities, which evaluate the consequences of hydromorphological degradation.

In contrast to organic pollution or acidification, hydromorphological degradation affects the benthic invertebrate community through a multitude of individual factors. Dams and impoundments alter flow conditions or temperature profiles (Ward & Stanford 1979). The loss of riparian vegetation affects production (Bunn et al. 1999) and water temperature (Sponseller et al. 2001), processes and parameters with an imminent influence on the benthic community. Anthropogenic alterations of the channel and the river-bed have a strong influence on microhabitat composition (Kemp et al. 1999), which has been argued as the primary factor influencing community structure and species richness (Beisel et al. 1998). Certain microhabitats are particularly affected by hydromorphological degradation and are inhabited by specialist taxa. For example, 103 benthic invertebrate taxa have a preference for woody debris in Central Europe (Hoffmann & Hering 2000), and this debris is often removed from the main channel. Approaches to assess the impact of hydromorphological alterations on the invertebrate fauna include only some impacts, such as dams (Marchant & Hehir 2002), reduced discharge (Brunke et al. 2001), habitat composition (Buffagni et al. 2001), fine sediment cover (Mebane 1999) and logging (Fore et al. 1996).

Multimetric systems are summing up parameters integrating different spatial and temporal scales (Karr 1994; Barbour et al. 1998; Karr & Chu 1999). Therefore, multimetric systems seem to be well suited to detect the impact of hydromorphological degradation on the invertebrate fauna, which is usually composed of several factors. Sometimes, but not always, these factors are linked.

The Multimetric Index EQI_M developed for mid-sized streams in lower mountainous areas of Germany aims for an integration of parameters potentially affected by different kinds of hydromorphological degradation. This is performed on two levels. Firstly, the "German Fauna Index", which includes taxa likely to respond to different components of morphological degradation, and secondly supplementary metrics, which cover additional parameters.

A crucial point for the development of assessment systems aiming to detect the effects of hydromorphological degradation is a profound knowledge on reference conditions. Particularly for stream types in the German lowlands and for medium-sized mountain streams no reference sites are available anymore. Therefore, additional information are used to define reference conditions, particularly historical information on river morphology and results of several national projects targeting on reference conditions, which are described in detail in LUA NRW (1999a, 1999b, 2000, 2001).

The multimetric system aims to assess the impact of hydromorphological degradation. However, the "German Fauna Index" appears also to be sensitive to organic pollution as both the "German Fauna Index" and the German Saprobic Index are strongly correlated (r^2 = 0.65; Table 14). The correlation of the "German Fauna Index" with the hydromorphological conditions is also strong (r^2 = 0.67), in contrast to the correlation of the

Saprobic Index with the Structure Index (r^2 = 0.42). Consequently, the "German Fauna Index", although somewhat sensitive to organic pollution, appears to deliver additional information. The occurrence and abundance of most taxa is affected by several parameters and their interactions and therefore, there is an inevitable overlap of taxa included into the Saprobic System and into the "German Fauna Index". Both metrics aim to utilise different characters of certain taxa: *Siphlonurus* sp. (Ephemeroptera) indicates high oxygen contents but also the presence of lentic sections and high stream dynamics. *Asellus aquaticus* (Crustacea) indicates low oxygen contents but also stagnation and low current velocities, which may also occur upstream of dams in unpolluted rivers. Furthermore, hydromorphological degradation and organic pollution often interact, e.g. in stagnant sections high BOD values may effect the community more seriously than in running sections. However, the most serious effect of hydromorphological degradation is the loss of lentic habitats; taxa preferring low current velocities are therefore often good indicators for morphological reference conditions, despite a low saprobic value (Hering et al. 2001).

The impact of organic pollution can be assessed with a comparatively low taxonomic resolution, e.g. the ASPT system, which is based on family level identifications. Most metrics used to assess the impact of hydromorphological degradation, however, are based on species level, since taxa occurring in certain habitats or preferring sites with a certain hydromorphological quality can be defined only on species level, while within genera or families the variability of habitat preferences is usually high (Appendix 3). This may indicate a general shift in stream assessment in Central Europe: organic pollution, which can easily be indicated by a large number of metrics, has widely disappeared, while the assessment of the remaining threats to aquatic biodiversity requires a high taxonomic resolution. As the saprobic assessment in Germany recently lead mainly to a "good" water quality class for the majority of streams, the assessment with the new Ecological Quality Index displays results from "bad" to "high" quality classes (Figure 29) thus, better reflecting the present quality of Central European rivers. In conclusion, the new Multimetric Index EQI_M works well in detecting the impact of hydromorphological degradation on the benthic invertebrate fauna even with other data sets, which have a sufficient taxonomic resolution.

3 Statistical tests for applying a minimum number of individuals for AQEM-method samples

Abstract

An "electronic subsampling technique" was developed and tested with benthic invertebrate samples taken in three German stream types to investigate, how strongly the number of individuals analysed influences the results. For each of 152 samples ("reference samples") 100 subsamples of the sizes 100, 200, 300, 500 and 700 individuals were generated randomly. To evaluate subsample deviation from the reference sample 45 metrics were calculated. In general, the variability of metric results increases with decreasing subsample size. Individual metrics show different sensitivity to decreasing subsample size. Three of the metrics tested (German Saprobic Index, German Fauna Index and Ecological Quality Index using Macroinvertebrates) are part of the German AQEM assessment system, for which they are transferred into quality classes. More than 40 % of the 100-individuals subsamples are classified into a different quality class compared to the reference samples, but less than 20 % for 700-individual subsamples. A certainty > 20 % is obtained with a subsample size of 300 individuals in lowland streams, whereas 700 individuals are needed to achieve the same level of confidence in mountain streams. Metrics, which rely on absolute abundances or abundance classes (e.g. BMWP, number of taxa) show higher sensitivity to a changing number of individuals than metrics, which depend on relative abundances (e.g. [%] lithal preferences, [%] of gatherers/collectors). Thus, the reliability of the metrics is related to subsample size, stream type and metric type.

3.1 "Electronic subsampling" of invertebrate samples: how many individuals are needed for a valid assessment result?

3.1.1 Introduction

River assessment with macroinvertebrates is always based on samples, which are supposed to reflect the biocoenosis of a reach. The intensity and methodology of sampling necessary for valid assessment results has been a matter of discussion in many papers (Barbour et al. 1996; Somers et al. 1998; Doberstein et al. 2000; King & Richardson 2002).
Assessment systems often rely on those specific sampling methods, which were also used to generate the data needed for developing the assessment systems (e.g. Armitage et al. 1983). However, many of these field and laboratory sampling and sorting methods are tedious and highly time consuming and are therefore not really suited for widespread application. While intense sampling effort is required to develop a system, applied assessment may be possible with considerably less time-consuming methods.
The aim of the AQEM-project was to develop an assessment system based on benthic macroinvertebrates meeting the requirements of the EU Water Framework Directive. Among others, the AQEM-project served for the development of assessment systems for five different stream types in Germany. For these stream types, metrics suited to assess the impact of morphological degradation on the benthic invertebrate fauna were developed (compare Chapter 2). Main indicative tools are a new metric with indicator taxa for certain natural and anthropogenically altered microhabitats ("German Fauna Index") and a Multimetric Index ("Ecological Quality Index using Macroinvertebrates"; Chapter 2; Lorenz et al. 2004). The development of this assessment system was based on a data set of benthic invertebrate samples, generated with a standardised method concerning sampling, sorting and identification (Hering et al. 2004). Due to the high sampling effort the original AQEM samples are characterised by large numbers of individuals and species and thus, by a high explanatory power.
For applied purposes it is desirable to reduce the sampling and sorting effort to increase the acceptance in water management or rapid bioassessment. However, reducing sampling or sorting effort should not result in a significant loss of quality in the results. Therefore, it is necessary to calculate the minimal number of individuals a sample should be composed of to achieve a valid assessment result. Critical analysis of the multi–step process from fieldwork

to data evaluation stimulated the idea that a simplification of the AQEM-method can be achieved by taking subsamples.

Rapid bioassessment protocols (Plafkin et al. 1989; Growns et al. 1997; Barbour et al. 1999) use fixed-count subsampling techniques. Comparative analysis of subsamples and complete samples revealed the weakness of too small subsamples (Doberstein et al. 2000). In fixed-count subsampling protocols the numbers of individuals needed for valid results vary between 100 (Barbour et al. 1996; Somers et al. 1998), 200 (Norris et al. 1995; King & Richardson 2002) or 300 and up to complete samples (Doberstein et al. 2000). Considering these results, the question arises, how many individuals must be analysed from an AQEM sample to achieve a valid assessment result.

For water management application the results of metrics are transformed into quality classes. Thus, it is also of interest, whether or not quality classes are affected by subsample sizes.

In particular, the following questions are addressed:

- How do results of subsamples vary in relation to the respective complete samples (reference samples) on the sample level and on the stream type level?
- How many individuals are necessary to achieve 90 % certainty that metrics results calculated with the subsample are the same as for the complete sample?
- How strongly are the results of different metrics affected by subsampling?
- How strongly is the designation of quality classes affected by subsampling?
- Is there a threshold sample size, below which the uncertainty of the results increases?
- Must different thresholds be defined for different metrics?
- Must different thresholds be defined for different stream types?
- What is the threshold for valid results if the AQEM sampling method is used with a fixed-count subsampling?

3.1.2 Materials and methods

Database

For this study, data collected on three German stream types in the AQEM-project were used: "mid-sized sand bottom streams in the German lowlands" (stream type 15), "small streams in lower mountainous areas of Germany" (stream type 5) and "mid-sized streams in lower mountainous areas of Germany" (stream type 9). For a more detailed description of the stream types compare Chapter 2 and Lorenz et al. (2004).

The streams were sampled in spring and summer 2000 (stream type 15 was additionally sampled in autumn 2000) using a multi-habitat-sampling technique (Hering et al. 2004). Altogether, 152 samples were included in the analysis. Each macroinvertebrate sample was made up of 20 "sampling units" covering a total area of 1.25 m^2; all organisms were picked out in the lab at standardised conditions. Before sorting, the samples were sieved through a 1 mm net for the lowland stream samples and a 2 mm net for the mountain stream samples. Organisms were usually identified to species level, except Oligochaeta and Diptera (family level) and Chironomidae (tribus level). Prior to data processing a taxonomical adjustment was applied (compare Nijboer & Schmidt-Kloiber 2004). The resulting taxa lists usually comprised very high numbers (up to 6275) of individuals (Table 16).

Table 16. Samples used for the electronic subsampling procedure. (Stream type number according to Sommerhäuser & Pottgiesser 2004; Appendix 1)

Stream type	Stream type	No. of samples	Ø Ind.	Min Ind.	Max Ind.	Ø Taxa	Min Taxa	Max Taxa	Samples > 700 Ind.
Mid-sized sand bottom streams in the German lowlands	15	54	1167	31	3452	40	20	59	35
Small streams in lower mountainous areas of Germany	5	58	1543	218	6275	55	25	88	45
Mid-sized streams in lower mountainous areas of Germany	9	40	1524	122	5494	56	18	79	31

Electronic subsampling

An electronic subsampling procedure was performed by generating random subsets of each of the 152 original taxa lists (in the following referred to as "original samples" or "reference samples"). For every original sample a total of 500 subsamples was generated, where 100 subsamples were generated for each of the following subsample sizes 100, 200, 300, 500 and 700 individuals. The randomiser selected individuals without returning them to the sample; thus, each individual could only be selected once per subsample. Every single subsampling procedure was performed based on a "complete" original taxa list, which was not altered by any previous subsampling procedure (Figure 31).

In a second step subsamples were generated containing exactly the same number of specimens as the original sample by applying the bootstrap algorithm (Efron & Tibshirani 1993). "Bootstrapping" is performed by randomly selecting an individual, recording it, and putting it back again. This was repeated as many times as individuals are present in the original sample. Afterwards, the variability of metrics in a sample can be estimate by computing 100 bootstrap samples for each of the 152 reference samples.

For comparative reasons only reference samples containing more than 700 organisms were analysed.

Both, for the original samples and for the two types of subsamples a selection of 45 widely used metrics were calculated with the AQEM-software (Hering et al. 2004), amongst others the German Saprobic Index (new version; compare Rolauffs et al. 2004), the German Fauna Index and the Ecological Quality Index (EQI_M) (for the list of metrics compare Table 17, Table 18, Table 19). The metric results of the original sample are referred to as "reference values".

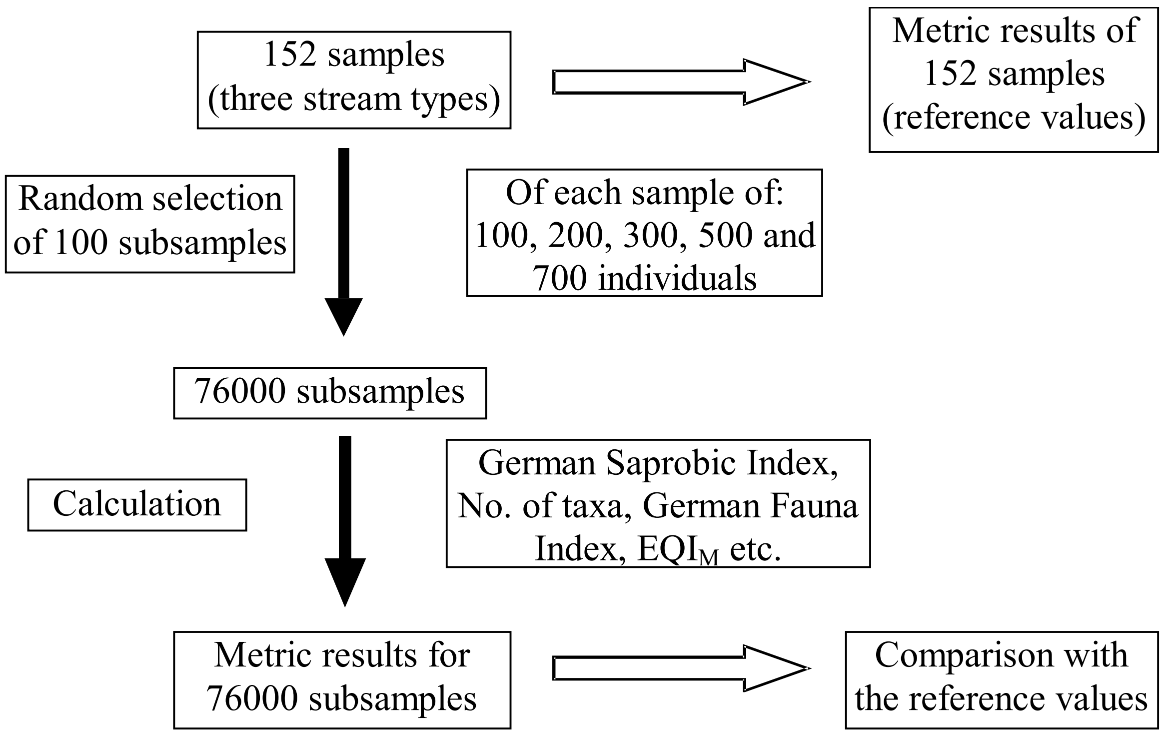


Figure 31. Flow chart of the electronic subsampling procedure.

In order to examine whether there is a difference between the metric result based on a subsampled taxa list and the respective "reference value" descriptive statistics was used, e.g. box-plots to display the variance of the metric results in relation to the subsample size. Concerning individual samples, each box presents the metric results of 100 subsamples. A comparison on stream type level, shows the deviation of the subsample results from the respective reference values in box plots, too, where each plot consists of (100 * number of reference samples) values. This visualises the variance of every metric in relation to the subsample size.

For each of the 45 metrics examined the results calculated with the subsampled taxa lists were compared to the respective reference values by calculating the relative deviation of each result from the reference value. Additionally, the standard deviation of the different values was calculated. The standard deviation delivers the range, in which two third of the results are to be expected. Thus, these values can be used to test, how seriously the individual metric results are affected by subsample size: low standard deviation means reliable results even for small subsamples.

Special emphasis was laid on those metrics, which are part of the German AQEM assessment system (Chapter 2; Lorenz et al. 2004); as part of the assessment procedure, the ranges of these metrics are individually divided into five quality classes ranging from 5 (high status) to 1 (bad status). Consequently, metric results from subsamples, which differ from the results of reference samples, can also be a source of error in the assignment to the different quality classes. For the German Saprobic Index, the German Fauna Index, the different metrics used for the Ecological Quality Index (EQI_M) and for the EQI_M itself, the quality class resulting from each subsample were calculated and then compared with the quality class of the reference values. Afterwards, the percentage of misclassification within a stream type in relation to the subsample size was calculated for each classified metric.

Furthermore, these metrics were subject to calculations with the bootstrap algorithm. The results of the bootstrap subsamples were also searched for misclassification in comparison to the original sample and the "normal" subsamples.

3.1.3 Results

Descriptive statistics

In Figure 32, the results of three metrics (German Fauna Index stream type 9, German Saprobic Index and the Multimetric Index EQI_M) are given for a single sampling site of stream type 9 (mid-sized mountain streams). In general, the variability of metric results decreases with increasing subsample size. This is also true on the stream type level (Figure 33). Of the three exemplary metrics the German Saprobic Index is least affected by decreasing subsample size at both subsample and at stream type level. At the stream type level this index has an average deviation of 0.04 units (range of possible metric results: 3.0 units) from the reference value even if the metric is calculated with only 100 subsampled individuals. The German Fauna Index and the Ecological Quality Index using

Macroinvertebrates (EQI_M) decrease on the stream type level from a mean deviation of 0.2 units and 0.4 units respectively in the 100-individuals subsamples to 0.05 (German Fauna Index) and 0.15 (EQI_M) in the 700-individuals subsamples. Both metrics have a possible range of 4.0 units. In contrast to these relatively small deviations the number of taxa varies extremely with the subsample size. In the 100-individuals subsamples, the average number of taxa not accounted for is 35 (75-percentile: 57 taxa). In the 300-individuals subsample a mean of 22 taxa is missing compared to the "original" samples. Even if 700 individuals are subsampled, an average of 11 taxa is still missed (75-percentile: 32 taxa). Comparable results have been found for the other two investigated stream types (stream type 15: 100 ind.: 25 taxa (75-percentile: 42), 300 ind.: 16 taxa (75-percentile: 33), 700 ind.: 8 (75-percentile: 25); stream type 5: 100 ind.: 34 (75-percentile: 62), 300 ind.: 22 (75-percentile: 47), 700 ind.: 12 (75-percentile: 35)).

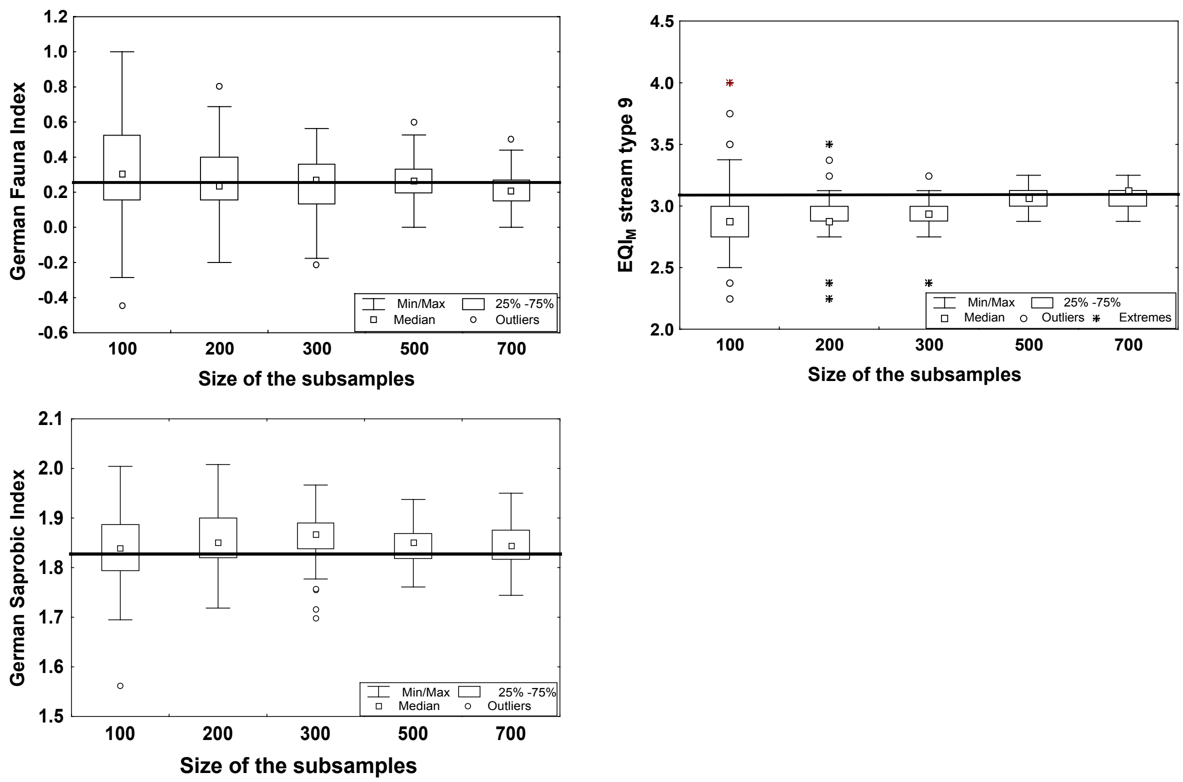


Figure 32. Variability of the German Fauna Index (for stream type 9), the Ecological Quality Index (EQI_M stream type 9) and the German Saprobic Index (new version) for one sampling site of stream type 9 for different subsample sizes. The horizontal lines in the middle show the metric result calculated with the complete taxa list.

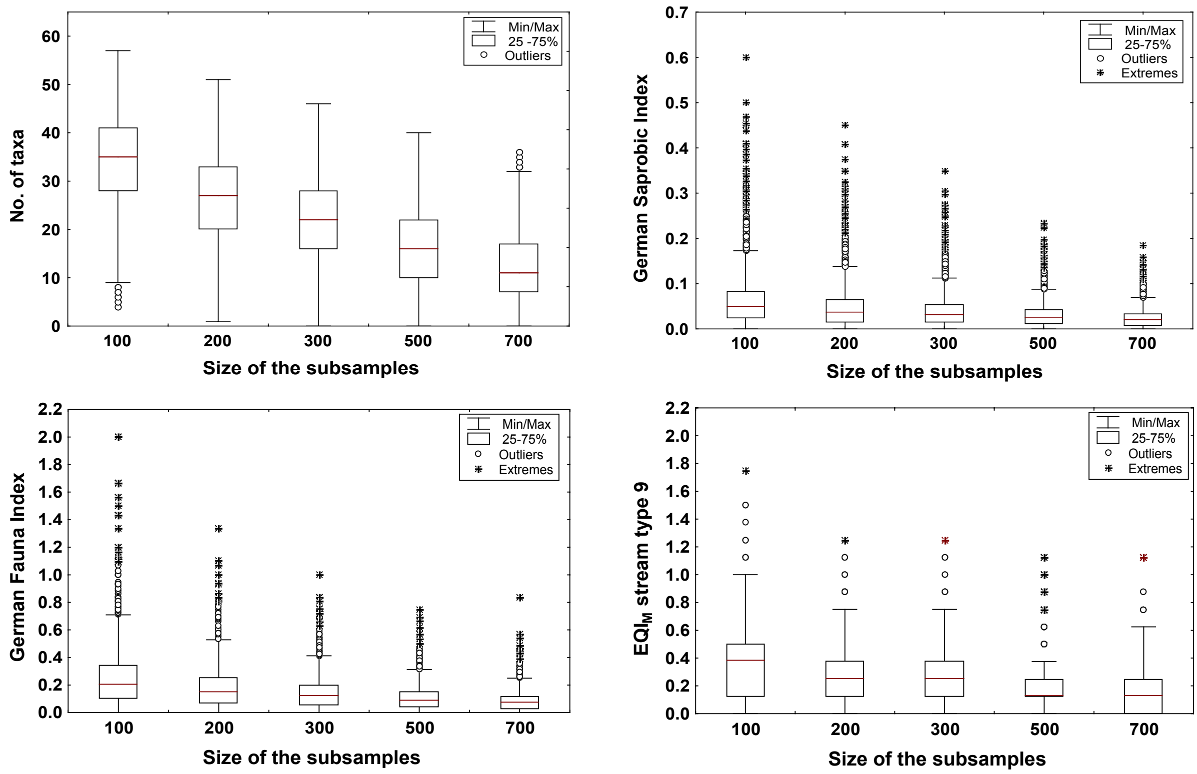


Figure 33. Absolute deviation of the metrics "No. of taxa", "German Saprobic Index (new version)", "German Fauna Index (for stream type 9)" and "Ecological Quality Index (EQI$_M$ stream type 9)" from the respective reference values for all samples (31) taken for mid-sized streams in lower mountainous areas (stream type 9); n = 31 sampling sites, respectively 3100 subsamples per subsample size.

Reliability of the metrics

The sensitivity of 45 metrics to reduced numbers of individuals was evaluated by comparing the relative deviation of the metric result calculated with the subsampled taxa lists to the respective reference value. The standard deviation of these deviations was also calculated (Table 17, Table 18, Table 19). While the mean relative deviation characterises a certain bias of the respective metric, the standard deviation displays the sensitivity of the metric for a given subsample size. Hence, in Table 17, Table 18 and Table 19 the metrics have been ordered by the lowest standard deviation in the 700-individuals subsamples.

The results reveal apparent differences between the metrics. Some metrics (e.g. German Saprobic Index, [%] lithal preferences, [%] phytal preferences, RETI) show only slight deviations even if the subsample size is small; others, like the number of taxa, the BMWP-score or [%] limno-rheophilous preferences display large differences to the reference values when calculated with a subsampled taxa list. Overall, the decrease of the standard deviation with increasing subsample size is obvious. Lowest standard deviations are smaller than 2 %, but they can also reach more than 100 %. The proportional deviation has been calculated in relation to the reference value so the standard deviation of these subsample results can outnumber the reference value by several factors.

Metrics, which depend on absolute abundances (e.g. BMWP, number of taxa, Margalef Diversity) display high positive mean deviations (reference value minus subsample result) in low subsample sizes, because the subsample size itself limits the possibility for high abundances. Thus, these metrics are more sensitive to small samples sizes than proportional metrics (e.g. [%] lithal preferences, [%] phytal preferences, RETI).

The reliability of the metrics differs only slightly between the three stream types. The two versions of the German Saprobic Index, ASPT, RETI, [%] lithal preferences and Shannon-Wiener-Diversity are always under the "best ten" metrics. The German Fauna Index, which uses different indicator taxa in the three stream types, performs similar in the 700 individuals subsamples (stream type 15: deviation = 0.2 $\pm$ 6.4; stream type 5: deviation = 1.9 $\pm$ 5.4; stream type 9: deviation = - 0.5 $\pm$ 6.6) but shows differences in the 100-individuals subsamples (stream type 15: deviation = - 0.5 $\pm$ 15.1; stream type 5: deviation = 4.8 $\pm$ 11.3; stream type 9: deviation = - 2.7 $\pm$ 19.6). Stream type specific differences can be found for the metric "[%] sand preferences (Type Psa)", which is most reliable in the sand bottom lowland streams (stream type 15: 100 ind.: deviation = - 0.1 $\pm$ 21.6; 700 ind.: deviation = - 0.1 $\pm$ 6.3) and less reliable in the mountain streams (stream type 5: 100 ind.: deviation = - 0.8 $\pm$ 42.8; 700 ind.: deviation = 0.1 $\pm$ 13.5; stream type 9: 100 ind.: deviation = - 0.5 $\pm$ 29.1; 700 ind.: deviation = 0.3 $\pm$ 9.3). The sensitivity of metrics addressing the proportion of other ecological traits (e.g. feeding preferences, microhabitat preferences or longitudinal zonation preferences) also differs between stream types.

To compare the reliability of the metrics between stream types the relative standard deviation (differences of metric results between subsample taxa lists and reference taxa lists) is crucial. In the 100-individuals subsamples only three metrics show a deviation of less than 10 % in stream type stream type 15, six in stream type 5 and seven in stream type 9 (including the ASPT, which has a standard deviation of 9.1 but a mean deviation of 3.2). In the 300-individuals subsamples 14 metrics have deviation below 10 % in stream type 15, 17 in stream type 5 and 15 in stream type 9. This number rises to 19 (stream type 15), 22 (stream type 5) and 24 (stream type 9) for subsample size 700.

Table 17. Mean relative deviation of the metric results compared to the reference sample (%) plus/minus standard deviation (%) for different subsample sizes (stream type 15; mid-sized sand bottom streams in the German lowlands).

Metric\Size of subsample	100	200	300	500	700
German Saprobic Index (new version)	0.1 ± 3.1	0.2 ± 2.5	0.2 ± 2.1	0.3 ± 1.6	0.2 ± 1.3
German Saprobic Index (old version)	-0.1 ± 5.2	-0.1 ± 4.3	0.0 ± 3.7	0.1 ± 2.6	-0.1 ± 1.9
Diversity (Shannon-Wiener-Index)	7.6 ± 9.0	4.2 ± 6.2	2.9 ± 5.0	1.6 ± 3.5	1.0 ± 2.8
Type Lit (Lithal: coarse gravel, stones, boulders; grain size > 2 cm) [%]	0.2 ± 11.8	0.2 ± 8.2	0.1 ± 6.1	0.0 ± 4.3	0.0 ± 3.0
Hyporhithral (greyling region) [%]	0.3 ± 12.3	0.1 ± 8.4	0.1 ± 6.4	-0.1 ± 4.5	0.1 ± 3.3
Type Phy (Phytal: algae, mosses and macrophytes including living parts of terrestrial plants) [%]	0.4 ± 12.5	0.0 ± 8.6	0.0 ± 6.6	0.1 ± 4.4	0.0 ± 3.3
Epipotamal (barbel region) [%]	0.3 ± 12.8	0.1 ± 8.5	0.1 ± 6.5	0.0 ± 4.5	0.1 ± 3.4
Gatherers/Collectors [%]	0.1 ± 12.0	0.0 ± 7.9	0.0 ± 6.4	0.0 ± 4.4	0.0 ± 3.4
RETI (Rhithron Feeding Type Index)	0.4 ± 12.4	0.1 ± 8.0	0.0 ± 6.4	0.1 ± 4.6	-0.1 ± 3.5
Metarhithral (lower-trout region) [%]	0.3 ± 15.3	0.1 ± 10.4	0.2 ± 8.0	-0.1 ± 5.7	0.0 ± 4.1
Grazer and scrapers [%]	0.6 ± 16.1	0.3 ± 10.9	0.1 ± 8.7	0.1 ± 6.0	0.0 ± 4.5
ASPT (Average Score per Taxon)	0.4 ± 11.6	-0.2 ± 9.5	-0.1 ± 8.0	-0.3 ± 6.3	-0.1 ± 5.4
Predators [%]	-0.1 ± 22.7	0.0 ± 15.0	0.2 ± 11.3	0.0 ± 7.9	0.0 ± 6.1
Type Psa (Psammal: sand; grain size 0.063 - 2 mm) [%]	-0.1 ± 21.6	-0.1 ± 15.0	0.1 ± 11.2	-0.1 ± 8.2	-0.1 ± 6.3
EQI_M stream type 15	0.3 ± 11.4	0.2 ± 9.7	0.4 ± 8.9	0.6 ± 7.3	0.5 ± 6.3
German Fauna Index stream type 15	-0.5 ± 15.1	-0.1 ± 11.8	-0.4 ± 9.7	-0.2 ± 7.5	0.2 ± 6.4
Shredders [%]	0.0 ± 25.2	0.0 ± 15.7	0.0 ± 13.6	0.0 ± 9.5	-0.1 ± 7.1
Type Aka (Akal: fine to medium-sized gravel; grain size 0.2 - 2 cm) [%]	-0.3 ± 30.7	-0.2 ± 21.4	-0.1 ± 16.9	-0.2 ± 11.8	-0.2 ± 8.2
Type RP (rheophil, occurring in streams; prefers zones with moderate to high current) [%]	0.0 ± 29.6	0.0 ± 21.7	0.0 ± 17.8	-0.3 ± 11.4	0.1 ± 8.5
Littoral [%]	0.2 ± 34.5	-0.5 ± 22.5	-0.1 ± 18.2	0.1 ± 13.6	0.2 ± 10.2
Epirhithral (upper-trout region) [%]	0.2 ± 38.6	0.7 ± 23.3	0.1 ± 19.0	-0.1 ± 13.8	0.2 ± 10.3
Type RL (rheo- to limnophil, usually found in streams; prefers slowly flowing streams and lentic zones; also found in standing waters) [%]	-0.2 ± 38.4	-0.1 ± 26.5	0.1 ± 20.5	0.2 ± 13.9	-0.3 ± 10.8
Diversity (Margalef Index)	40.3 ± 15.5	30.2 ± 15.7	24.3 ± 15.3	16.6 ± 13.9	12.0 ± 12.9
Type Pel (Pelal: mud; grain size < 0.063 mm) [%]	-0.1 ± 42.2	0.0 ± 28.9	0.0 ± 22.3	0.0 ± 16.6	-0.1 ± 13.4
Metapotamal (brass region) [%]	0.3 ± 44.5	0.7 ± 31.7	-0.2 ± 25.4	0.1 ± 18.5	0.5 ± 14.0
Number of indicator taxa SI new	58.9 ± 12.7	46.1 ± 14.1	37.9 ± 14.6	26.9 ± 14.6	19.5 ± 14.8
BMWP (Biological Monitoring Working Party)	52.8 ± 14.2	40.6 ± 15.6	33.3 ± 15.7	23.2 ± 15.6	17.1 ± 15.3
Number of taxa	61.3 ± 10.7	48.5 ± 13.1	40.1 ± 14.2	28.5 ± 14.9	20.7 ± 15.4
Hypocrenal (spring-brook) [%]	1.5 ± 48.9	-0.2 ± 36.5	-0.3 ± 27.2	0.3 ± 19.3	0.0 ± 16.1
Number of indicator taxa stream type 15	61.8 ± 14.5	48.4 ± 16.1	40.0 ± 16.9	28.3 ± 16.9	20.4 ± 16.7
Number of indicator taxa SI old	59.5 ± 17.6	46.9 ± 19.2	38.5 ± 19.2	27.3 ± 18.1	19.7 ± 17.6
Type POM (particulate organic matter, such as woody debris, CPOM, FPOM) [%]	2.0 ± 65.0	1.2 ± 45.1	0.2 ± 38.5	-0.7 ± 28.8	0.7 ± 20.0
Trichoptera [%]	-0.4 ± 67.0	0.1 ± 50.8	1.0 ± 34.8	0.0 ± 26.9	-0.1 ± 21.9
Active filter feeders [%]	1.1 ± 73.5	-0.5 ± 50.7	-0.1 ± 40.6	-0.4 ± 30.2	-0.6 ± 24.7
Passive filter feeders [%]	-1.2 ± 110.2	-0.6 ± 71.3	1.3 ± 54.7	-1.3 ± 42.1	0.7 ± 32.9
Type IN (indifferent, no preference for a certain current velocity) [%]	-3.5 ± 127.8	-0.4 ± 75.3	0.7 ± 58.2	0.3 ± 41.9	0.8 ± 34.6
Type LR (limno- to rheophil, preferably occurring in standing waters but regularly occurring in slowly flowing streams) [%]	0.4 ± 126.7	-0.5 ± 89.3	-1.0 ± 71.0	-0.4 ± 53.1	-0.7 ± 41.6

Metric\Size of subsample	100	200	300	500	700
Type RB (rheobiont, occurring in streams; bound to zones with high current) [%]	1.8 ± 168.5	1.8 ± 122.7	3.4 ± 91.9	-1.9 ± 70.7	-0.6 ± 55.3
Hypopotamal (brackish water) [%]	-0.3 ± 162.4	0.5 ± 128.1	0.3 ± 98.0	1.0 ± 68.9	1.0 ± 55.9
Xylophagous taxa [%]	-9.4 ± 267.4	-1.5 ± 159.6	2.9 ± 122.7	2.1 ± 83.6	-1.3 ± 67.6
Type LB (limnobiont, occurring only in standing waters) [%]	-6.6 ± 261.5	-8.9 ± 173.7	-3.6 ± 133.1	-1.0 ± 98.2	-4.1 ± 69.9
Crenal (spring) [%]	4.6 ± 206.9	-6.5 ± 169.3	1.1 ± 125.2	3.1 ± 91.6	0.8 ± 73.1
Type Arg (Argyllal: silt, loam, clay; grain size < 0.063 mm) [%]	1.0 ± 248.2	-2.4 ± 188.0	-2.5 ± 143.1	-0.6 ± 102.6	0.6 ± 77.8
Type LP (limnophil, preferably occurring in standing waters; avoids current; rarely found in slowly flowing streams) [%]	2.8 ± 267.5	0.4 ± 192.7	2.7 ± 149.0	-3.2 ± 114.3	2.5 ± 84.0

Table 18. Mean relative deviation of the metric results compared to the reference sample (%) plus/minus standard deviation (%) for different subsample sizes (stream type 5; small streams in lower mountainous areas of Germany).

Metric\Size of subsample	100	200	300	500	700
Diversity (Shannon-Wiener-Index)	7.6 ± 4.7	4.2 ± 3.4	2.8 ± 2.7	1.5 ± 1.9	0.9 ± 1.5
German Saprobic Index (new version)	-0.5 ± 4.0	-0.4 ± 3.0	-0.2 ± 2.5	-0.1 ± 1.9	-0.2 ± 1.6
German Saprobic Index (old version)	-0.5 ± 4.4	-0.4 ± 3.2	-0.3 ± 2.7	-0.2 ± 2.0	-0.1 ± 1.7
RETI (Rhithron Feeding Type Index)	0.0 ± 8.1	0.1 ± 5.6	0.1 ± 4.4	0.1 ± 3.2	0.0 ± 2.5
Type Lit (Lithal: coarse gravel, stones, boulders; grain size > 2 cm) [%]	0.0 ± 9.8	0.1 ± 6.5	-0.1 ± 5.2	0.0 ± 3.7	0.0 ± 2.9
ASPT (Average Score per Taxon)	-2.4 ± 7.2	-2.0 ± 5.5	-1.5 ± 4.8	-1.1 ± 3.6	-0.7 ± 3.0
Metarhithral (lower-trout region) [%]	0.0 ± 10.1	0.2 ± 7.0	0.0 ± 5.6	0.0 ± 4.0	0.0 ± 3.1
Hyporhithral (greyling region) [%]	-0.1 ± 10.6	0.2 ± 7.2	0.0 ± 5.7	0.0 ± 4.1	0.0 ± 3.2
Grazer and scrapers [%]	0.0 ± 12.2	0.1 ± 8.3	0.0 ± 6.4	0.1 ± 4.7	0.0 ± 3.7
Epirhithral (upper-trout region) [%]	-0.1 ± 12.3	0.1 ± 8.7	-0.1 ± 6.8	-0.1 ± 4.9	0.0 ± 3.8
Gatherers/Collectors [%]	-0.2 ± 13.8	0.1 ± 9.4	-0.1 ± 7.4	0.0 ± 5.2	0.0 ± 3.9
Type RP (rheophil, occurring in streams; prefers zones with moderate to high current) [%]	0.1 ± 14.3	0.1 ± 10.1	0.0 ± 7.8	0.1 ± 5.8	0.1 ± 4.5
Type Phy (Phytal: algae, mosses and macrophytes including living parts of terrestrial plants) [%]	0.1 ± 15.6	0.2 ± 10.6	0.0 ± 8.4	-0.1 ± 6.1	0.1 ± 4.6
Epipotamal (barbel region) [%]	-0.1 ± 16.9	0.0 ± 11.4	0.1 ± 8.9	0.2 ± 6.5	0.1 ± 5.1
German Fauna Index stream type 5	4.8 ± 11.3	4.0 ± 9.0	3.4 ± 7.5	2.6 ± 6.0	1.9 ± 5.4
EQI_M stream type 5 spring	10.2 ± 8.9	6.7 ± 8.3	5.1 ± 7.6	2.9 ± 6.0	1.7 ± 5.5
Hypocrenal (spring-brook) [%]	-0.2 ± 18.2	0.3 ± 12.6	-0.3 ± 9.9	0.1 ± 7.1	0.1 ± 5.6
Type Aka (Akal: fine to medium-sized gravel; grain size 0.2 - 2 cm) [%]	0.0 ± 19.8	-0.1 ± 13.7	0.1 ± 10.9	0.0 ± 7.9	0.2 ± 6.2
Predators [%]	0.6 ± 25.4	0.3 ± 17.7	0.1 ± 14.0	-0.1 ± 10.0	0.0 ± 7.3
Diversity (Margalef Index)	30.9 ± 10.9	21.7 ± 10.4	16.8 ± 9.6	11.0 ± 8.5	7.7 ± 7.8
Shredders [%]	0.0 ± 27.0	0.2 ± 19.2	0.6 ± 15.2	0.1 ± 10.6	0.1 ± 8.1
EQI_M stream type 5 summer	13.3 ± 13.4	10.9 ± 12.5	9.7 ± 11.0	7.3 ± 9.2	5.6 ± 8.7
BMWP (Biological Monitoring Working Party)	42.5 ± 12.0	31.1 ± 12.1	24.9 ± 11.6	17.2 ± 10.8	12.5 ± 10.3
Type RB (rheobiont, occurring in streams; bound to zones with high current) [%]	0.2 ± 38.8	0.2 ± 27.2	-0.2 ± 20.3	-0.3 ± 14.3	-0.1 ± 10.7
Number of taxa	57.1 ± 8.4	44.2 ± 9.9	36.3 ± 10.5	25.7 ± 11.3	18.9 ± 11.9
Littoral [%]	-0.5 ± 40.8	0.4 ± 28.3	0.0 ± 22.2	-0.2 ± 15.9	0.0 ± 11.9
Number of indicator taxa SI new	57.4 ± 10.2	44.3 ± 11.6	36.3 ± 12.2	25.5 ± 12.6	18.8 ± 12.9

Metric\Size of subsample	100	200	300	500	700
Number of indicator taxa SI old	52.2 ± 13.1	39.5 ± 13.8	31.8 ± 13.9	22.1 ± 13.7	16.2 ± 13.2
Type Psa (Psammal: sand; grain size 0.063 - 2 mm) [%]	-0.8 ± 42.8	-0.3 ± 30.7	0.5 ± 23.1	-0.2 ± 17.4	0.1 ± 13.5
Type Pel (Pelal: mud; grain size < 0.063 mm) [%]	-0.9 ± 52.7	0.5 ± 34.5	0.5 ± 27.9	-0.5 ± 19.5	0.0 ± 13.7
Type POM (particulate organic matter, such as woody debris, CPOM, FPOM) [%]	-0.6 ± 46.0	-0.9 ± 31.4	-0.4 ± 25.1	-0.3 ± 18.4	0.1 ± 13.9
Number of indicator taxa stream type 5	58.4 ± 11.9	45.5 ± 13.5	37.5 ± 14.1	26.5 ± 14.3	19.7 ± 14.3
Type RL (rheo- to limnophil, usually found in streams; prefers slowly flowing streams and lentic zones; also found in standing waters) [%]	-0.3 ± 45.0	0.0 ± 31.2	0.2 ± 24.9	-0.4 ± 18.4	0.0 ± 14.6
Crenal (spring) [%]	0.1 ± 69.4	0.4 ± 50.1	1.2 ± 34.7	0.0 ± 29.5	0.2 ± 21.7
Metapotamal (brass region) [%]	0.1 ± 81.1	1.0 ± 52.0	0.5 ± 41.8	-0.6 ± 29.9	0.5 ± 22.5
Passive filter feeders [%]	0.9 ± 91.8	0.7 ± 57.2	-0.6 ± 54.9	0.5 ± 34.3	0.0 ± 29.4
Type IN (indifferent, no preference for a certain current velocity) [%]	2.3 ± 138.6	0.8 ± 103.1	0.2 ± 80.0	-0.6 ± 56.9	-0.6 ± 44.4
Type LR (limno- to rheophil, preferably occurring in standing waters but regularly occurring in slowly flowing streams) [%]	-2.2 ± 191.5	-1.7 ± 130.5	0.1 ± 102.6	1.3 ± 69.0	-1.0 ± 51.8
Hypopotamal (brackish water) [%]	-2.6 ± 230.9	-3.0 ± 158.7	-2.6 ± 124.3	-0.6 ± 86.2	1.0 ± 68.7
Active filter feeders [%]	-5.6 ± 243.8	2.8 ± 153.7	3.3 ± 120.7	-2.2 ± 91.1	-0.6 ± 71.1
Type Arg (Argyllal: silt, loam, clay; grain size < 0.063 mm) [%]	-2.5 ± 260.3	5.4 ± 164.5	-1.1 ± 135.7	-7.9 ± 99.9	0.4 ± 73.8
Type LP (limnophil, preferably occurring in standing waters; avoids current; rarely found in slowly flowing streams) [%]	-0.6 ± 240.0	1.7 ± 163.8	2.2 ± 134.3	-0.6 ± 104.7	2.4 ± 79.6
Miners [%]	8.8 ± 221.6	-6.9 ± 225.3	-4.0 ± 177.5	0.5 ± 104.0	2.6 ± 81.3
Type LB (limnobiont, occurring only in standing waters) [%]	30.6 ± 353.8	-20.4 ± 449.5	1.4 ± 294.6	1.9 ± 246.2	10.5 ± 179.3
Xylophagous taxa [%]	7.8 ± 587.3	13.9 ± 378.0	-6.1 ± 334.7	-4.6 ± 272.0	9.3 ± 202.6

Table 19. Mean relative deviation of the metric results compared to the reference sample (%) plus/minus standard deviation (%) for different subsample sizes (stream type 9; mid-sized streams in lower mountainous areas of Germany).

Metric\Size of subsample	100	200	300	500	700
German Saprobic Index (old version)	-1.3 ± 4.1	-1.1 ± 3.1	-1.0 ± 2.6	-0.8 ± 2.0	-0.7 ± 1.7
German Saprobic Index (new version)	-0.5 ± 4.2	-0.5 ± 3.1	-0.6 ± 2.7	-0.4 ± 2.1	-0.5 ± 1.7
Diversity (Shannon-Wiener-Index)	7.9 ± 5.2	4.4 ± 3.7	3.0 ± 3.0	1.7 ± 2.2	1.1 ± 1.7
Type Lit (Lithal: coarse gravel, stones, boulders; grain size > 2 cm) [%]	0.0 ± 8.0	0.2 ± 5.5	-0.1 ± 4.3	-0.1 ± 3.2	0.1 ± 2.5
RETI (Rhithron Feeding Type Index)	-0.3 ± 9.3	0.2 ± 6.4	0.1 ± 5.0	0.0 ± 3.6	0.1 ± 2.9
Hyporhithral (greyling region) [%]	-0.2 ± 9.9	0.1 ± 6.5	0.0 ± 5.4	0.0 ± 3.7	0.0 ± 3.0
Metarhithral (lower-trout region) [%]	-0.4 ± 10.0	0.1 ± 6.4	-0.1 ± 5.4	0.0 ± 3.7	0.1 ± 3.0
Type Phy (Phytal: algae, mosses and macrophytes including living parts of terrestrial plants) [%]	-0.4 ± 10.3	0.0 ± 7.2	-0.1 ± 5.8	0.1 ± 4.1	0.0 ± 3.2
Grazer and scrapers [%]	-0.1 ± 11.3	0.2 ± 7.7	0.1 ± 6.0	0.0 ± 4.4	0.1 ± 3.4
Epirhithral (upper-trout region) [%]	-0.3 ± 13.1	0.1 ± 8.8	-0.1 ± 7.2	0.0 ± 5.1	0.2 ± 4.0
Gatherers/Collectors [%]	0.1 ± 13.5	0.0 ± 9.0	0.2 ± 7.4	0.1 ± 5.2	0.0 ± 4.1
ASPT (Average Score per Taxon)	3.2 ± 9.1	2.1 ± 7.3	1.6 ± 6.6	1.2 ± 5.1	1.0 ± 4.3
Epipotamal (barbel region) [%]	-0.3 ± 15.1	-0.1 ± 10.2	0.2 ± 8.0	0.2 ± 5.5	0.0 ± 4.5

Metric\Size of subsample	**100**	**200**	**300**	**500**	**700**
EQI_M stream type 9	3.8 ± 14.1	5.7 ± 9.9	8.3 ± 5.9	6.7 ± 5.5	5.4 ± 5.1
Type RP (rheophil, occurring in streams; prefers zones with moderate to high current) [%]	-0.2 ± 16.8	0.0 ± 11.4	0.1 ± 9.0	0.1 ± 6.6	0.1 ± 5.3
Hypocrenal (spring-brook) [%]	-0.4 ± 21.0	0.2 ± 14.3	0.2 ± 11.3	0.1 ± 8.3	0.2 ± 6.2
German Fauna Index stream type 9	-2.7 ± 19.6	-2.1 ± 12.9	-1.4 ± 10.7	-0.7 ± 8.6	-0.5 ± 6.6
Predators [%]	-0.5 ± 22.3	0.2 ± 15.5	0.0 ± 11.9	-0.1 ± 8.7	0.0 ± 6.7
Littoral [%]	-0.7 ± 25.1	0.0 ± 16.8	0.2 ± 13.2	0.2 ± 9.6	-0.1 ± 7.4
Diversity (Margalef Index)	32.6 ± 12.0	23.2 ± 11.1	18.3 ± 10.4	12.5 ± 9.0	9.2 ± 7.7
Type Aka (Akal: fine to medium-sized gravel; grain size 0.2 - 2 cm) [%]	-0.6 ± 24.9	-0.3 ± 17.0	0.2 ± 13.7	0.4 ± 10.0	0.1 ± 7.9
Type Pel (Pelal: mud; grain size < 0.063 mm) [%]	0.3 ± 26.9	-0.6 ± 18.4	0.3 ± 15.4	0.2 ± 10.4	-0.1 ± 8.3
Type Psa (Psammal: sand; grain size 0.063 - 2 mm) [%]	-0.5 ± 29.1	-0.5 ± 20.5	0.5 ± 16.0	0.2 ± 11.3	0.3 ± 9.3
Number of taxa	58.5 ± 8.3	45.8 ± 9.2	38.0 ± 9.6	27.7 ± 9.7	21.0 ± 9.5
BMWP (Biological Monitoring Working Party)	46.8 ± 11.8	35.4 ± 11.8	29.0 ± 11.5	20.7 ± 10.8	15.4 ± 10.1
Number of indicator taxa SI new	58.6 ± 9.6	45.6 ± 10.5	37.6 ± 10.9	27.3 ± 10.8	20.5 ± 10.5
Type RB (rheobiont, occurring in streams; bound to zones with high current) [%]	-0.1 ± 35.2	-0.2 ± 23.2	-0.3 ± 17.6	-0.4 ± 13.0	-0.1 ± 10.5
Metapotamal (brass region) [%]	-1.3 ± 35.1	-0.6 ± 24.1	0.0 ± 18.4	0.2 ± 13.5	-0.1 ± 10.5
Number of indicator taxa SI old	52.6 ± 12.5	40.1 ± 12.9	32.5 ± 13.0	23.4 ± 12.1	17.3 ± 11.3
Number of Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Odonata and Bivalvia taxa	59.5 ± 11.7	46.9 ± 12.4	38.8 ± 12.4	28.4 ± 11.9	21.5 ± 11.4
Shredders [%]	-1.0 ± 37.3	0.1 ± 26.0	0.0 ± 20.1	0.1 ± 14.1	0.2 ± 11.7
Number of indicator taxa stream type 9	64.9 ± 11.1	51.3 ± 11.7	42.4 ± 12.0	30.9 ± 11.9	23.0 ± 11.7
Type POM (particulate organic matter, such as woody debris, CPOM, FPOM) [%]	0.0 ± 39.7	0.8 ± 27.9	0.6 ± 23.1	-0.2 ± 16.3	-0.1 ± 12.3
Type RL (rheo- to limnophil, usually found in streams; prefers slowly flowing streams and lentic zones; also found in standing waters) [%]	-0.4 ± 38.1	-0.8 ± 26.5	0.6 ± 21.4	0.0 ± 15.4	-0.3 ± 12.7
Passive filter feeders [%]	1.0 ± 42.8	-0.8 ± 31.7	-0.4 ± 24.4	0.5 ± 17.6	-0.4 ± 13.4
Crenal (spring) [%]	-0.9 ± 73.4	1.7 ± 49.3	-0.6 ± 38.7	-0.4 ± 29.5	0.3 ± 22.4
Type IN (indifferent, no preference for a certain current velocity) [%]	-0.2 ± 95.2	-0.2 ± 67.6	-0.7 ± 53.7	-0.2 ± 39.2	0.1 ± 30.1
Hypopotamal (brackish water) [%]	-0.9 ± 101.5	0.0 ± 69.8	-0.9 ± 56.9	-0.3 ± 40.3	-0.4 ± 31.4
Type LB (limnobiont, occurring only in standing waters) [%]	-14.0 ± 171.5	2.9 ± 101.5	9.9 ± 76.9	-1.5 ± 53.7	-0.7 ± 44.2
Type Arg (Argyllal: silt, loam, clay; grain size < 0.063 mm) [%]	3.8 ± 150.8	2.0 ± 105.0	4.9 ± 81.8	-0.4 ± 61.7	1.3 ± 48.7
Active filter feeders [%]	1.6 ± 185.5	-1.6 ± 117.8	0.0 ± 100.8	0.9 ± 75.3	-0.8 ± 57.9
Xylophagous taxa [%]	-1.0 ± 195.1	1.0 ± 138.1	-1.8 ± 112.4	0.8 ± 82.8	0.0 ± 66.7
Type LR (limno- to rheophil, preferably occurring in standing waters but regularly occurring in slowly flowing streams) [%]	0.3 ± 227.9	-4.8 ± 163.6	0.4 ± 124.0	-2.6 ± 95.1	-1.4 ± 72.6
Miners [%]	5.6 ± 198.7	-0.9 ± 155.5	-1.4 ± 126.8	-0.9 ± 91.3	-2.6 ± 72.9
Type LP (limnophil, preferably occurring in standing waters; avoids current; rarely found in slowly flowing streams) [%]	1.9 ± 346.3	1.2 ± 236.9	7.6 ± 173.2	0.5 ± 132.9	6.1 ± 104.4

Misjudgement in quality classes

For those metrics, which are part of the German AQEM assessment system (compare Chapter 2; Lorenz et al. 2004) it was tested whether there is a change in the quality class calculated with the subsamples compared to the reference taxa lists. As a part of the assessment procedure, each metric result is converted into a quality class: the German Saprobic Index (new version), German Fauna Index, the different metrics used for the Ecological Quality Index (EQI_M) (compare Table 20) and the EQI_M itself. Thus, for each metric and each subsample size the percentage of misjudgement (incorrect assignment of quality class in comparison to the reference sample) was calculated (Table 20). The decreasing percentage of misclassified samples with increasing subsample sizes is obvious. Metrics, which are based on abundances and/or abundance classes (German Fauna Index, [%] Trichoptera, BMWP, No. of EPTCBO-taxa) are most affected by subsampling and display the highest proportion of misclassification. Since the Multimetric Index EQI_M is calculated with the quality classes of the individual metrics, the misclassification of the EQI_M is dependent on assignment errors of the single metrics. A high percentage of misclassified samples is especially common with small subsample sizes (up to 300 individuals). Part of the EQI_M for the mountain streams (stream types 5 and 9) are two metrics (Shannon-Wiener-Diversity in both; BMWP in stream type 5; No. of EPTCBO-taxa in stream type 9), which reveal misclassifications of more than 50 % in the subsample sizes 100-300 individuals.

The results of the bootstrap samples (last column; Table 20) deliver mainly a decrease in misclassifications compared to the 700-individuals subsamples. The difference is large for the Multimetric Index EQI_M and the German Fauna Index in stream types 5 (German Fauna Index: 7.4 %) and 9 (EQI_M: 9.3 %) and small for metrics addressing the proportion of ecological traits in all three stream types (e.g. [%] gatherers/collectors in stream type 15: difference 0.3 %, [%] xylophagous taxa, shredder, active and passive filter feeders in stream type 9: difference 0.3 %).

Table 20. Misjudgement of the quality classes (%) for the stream types 15, 5 and 9 in relation to the quality classes calculated with the reference samples.

			No. of individuals in the subsamples					
Stream type	**Metric**		**100**	**200**	**300**	**500**	**700**	**Bootstrap**
15 mid-sized sand bottom streams in the German lowlands	German Saprobic Index (new version)		8.7	5.7	5.1	3.9	2.8	2.2
	Multimetric Index (EQI_M) stream type 15		29.9	24.5	21.6	15.2	11.3	12.9
	EQI_M stream type 15	German Fauna Index stream type 15	34.1	27.3	24.1	16.1	11.8	10.2
		[%] Gatherers/collectors	17.5	11.5	10.4	7.2	6.0	5.7
		[%] Littoral preferences	16.2	12.4	8.0	5.7	5.1	4.4
		[%] Pelal preferences	17.9	11.3	9.0	5.7	3.6	3.6
		[%] Rheophilous preferences	10.2	6.9	4.8	3.3	2.7	5.6
		[%] Trichoptera	37.9	33.6	25.8	21.0	16.7	15.6
5 small streams in lower mountainous areas of Germany	German Saprobic Index (new version)		14.4	11.2	8.8	7.4	7.4	3.0
	Multimetric Index (EQI_M) stream type 5 Spring		45.0	38.3	32.9	25.0	20.6	13.1
	Multimetric Index (EQI_M) stream type 5 Summer		42.6	38.2	34.8	22.0	19.2	9.8
	EQI_M stream type 5	German Fauna Index stream type 5	36.2	31.2	26.8	19.4	17.4	10.0
		BMWP	95.6	93.6	86.4	66.9	52.6	29.0
		Shannon-Wiener-Diversity	58.8	38.4	26.4	14.0	9.4	9.4
		[%] Hyporhithral preferences	16.8	11.3	8.3	6.9	5.4	5.3
		[%] Hypocrenal preferences	37.1	31.4	25.0	20.8	15.3	13.1
		[%] Akal preferences	30.6	24.7	19.7	14.7	10.4	11.2
		[%] Phytal preferences	26.2	19.2	15.2	10.8	7.3	6.6
9 mid-sized streams in lower mountainous areas of Germany	German Saprobic Index (new version)		3.2	1.4	0.8	0.7	0.2	0.2
	Multimetric Index (EQI_M) stream type 9		32.2	29.2	28.1	23.1	20.5	11.2
	EQI_M stream type 9	German Fauna Index stream type 9	45.5	35.7	30.1	23.2	17.4	14.8
		No. of EPTCBO-taxa	93.5	92.2	86.5	67.0	55.2	41.1
		[%] Xylophagous taxa, shredder, active and passive filter feeders	20.3	13.9	11.0	8.2	6.3	6.0
		[%] Akal, lithal and psammal preferences	32.2	21.5	16.4	10.4	8.0	5.5
		Shannon-Wiener-Diversity	65.8	48.5	37.2	26.1	20.1	13.6

3.1.4 Discussion

Results of bioassessment with macroinvertebrates are largely dependent on (1) the method applied in the field, (2) the method of sorting the sample and the number of specimens evaluated (e.g. Doberstein et al. 2000) and (3) the taxonomic precision applied in identification (Schmidt-Kloiber & Nijboer 2004). To gain comparable results each of these steps need to be standardised. A method suited for application in water management should be as cheap as possible and should deliver as much information as necessary. Therefore, protocols applied in scientific studies need to be simplified to meet the requirements of water management; simplification can either address field methods, lab sorting or the level of identification.

The AQEM-method for invertebrate sampling (Hering et al. 2004) is likely to be used in several countries throughout Europe. However, the sampling process can result in high numbers of specimens, which limits its applicability in routine water management. Since the sampling method itself cannot be simplified without loss of information on the taxa living in certain habitats and the assessment method is based on species level identification, a reduction of the number of specimens is likely the best suited way to simplify the method. This could be done by a subsampling procedure, the pros and cons of which have been discussed by several authors (e.g. Courtemanch 1996; Vinson & Hawkins 1996; Walsh 1997; Doberstein et al. 2000; King & Richardson 2002).

In general, there are two alternatives of subsampling procedures: fixed-count methods (e.g. Barbour et al. 1996, 1999) or area/time related methods (e.g. Armitage et al. 1983). Fixed-count methods often deal with 100 (Barbour et al. 1996; Growns et al. 1997; Somers et al. 1998) or 200 (Norris et al. 1995; King & Richardson 2002) individuals. My approach was to simulate different subsample sizes to detect significant changes in the reliability of metrics with increasing subsample sizes and within stream types. Not surprisingly, the overall results display a decrease of variability with increasing subsample size. However, the sensitivity of metrics for a decreasing subsample size varies widely. A "key break point" in reliability is not detectable in the range of 100 to 700 individuals; but the decrease of the proportional standard deviation is low between the subsample sizes 300 to 700 individuals and high between 100 and 300 individuals. Some examples from stream type 9: [%] gatherers/collectors: subsample size 100-300 individuals, decrease of standard deviation: 6.1 – subsample size 300-700 individuals, decrease of standard deviation: 3.4; [%] rheobiont taxa: 100-300 individuals, decrease of standard deviation: 17.6 – 300-700 individuals, decrease of standard deviation: 7.1. Only three metrics in stream type 15, six metrics in stream type 5 and seven metrics in stream type 9 show less than 10 % proportional deviation in subsample sizes of 100 individuals. About twice as many metrics have less than 10 % proportional deviation in subsample sizes of 300 individuals. Thus, the reliability of the metrics is far better if at least 300 organisms are taken into account.

In contrast to results presented by Doberstein et al. (2000) some metrics based on relative abundance (e.g. [%] lithal preferences, [%] phytal preferences) performed well and showed only slight variability even in small subsample sizes. On the other hand, some metrics based on (relative) numbers/abundances (e.g. [%] Trichoptera) or richness measures (No. of taxa, No. of EPTCBO-taxa) yield the highest errors in small subsample sizes and display a high variability in the results. Especially the number of taxa varies extremely even if 500 to 700 individuals are examined. Thus, in contrast to Larsen (1998) the numerical richness of the subsamples would not be a good indicator of the overall richness in the samples. The data did not show that an asymptote on taxon richness is reached even if 500 or 700 individuals are considered (compare also May 1975).

Somers et al. (1998) investigated subsamples of 100, 200 and 300 individuals, but did not consider higher numbers of individuals, including the complete samples. Therefore, their suggestion for a minimum number was 100 individuals for rapid bioassessment and 200 to 300 individuals, if richness measures are applied. In contrast, my study showed a significant increase of reliability if 300 individuals instead of 100 or 200 organisms are subsampled. Furthermore, the results reveal a comparatively small gain of information in 500 or 700-individuals subsamples compared to 300-individuals subsamples. However, many metrics reach less than 10 % standard deviation, consequently a good reliability, only with 700-individuals subsamples.

Comparing the results to Barbour & Gerritsen (1996), Somers et al. (1998) and King & Richardson (2002) it must be considered that both papers deal with samples taken in lakes; the diversity of macroinvertebrates in lakes is usually lower than in streams. Thus, species diversity or richness measures are likely to approach an asymptote for smaller subsample sizes already. In the stream types investigated in this study reliable results cannot be attained with subsample sizes of less than 300 individuals.

An important aspect of assessment systems is the transformation of metric results into quality classes. To ease data interpretation single metric or multimetric results are often assigned into quality classes (e.g. Saprobic Systems: DEV 1992). It is of importance for routine water management if small numbers of individuals in a (sub)sample mislead the assessment of a site. Thus, subsampling induced variability in the results can affect the assignment to a quality class and can lead to misclassification in relation to the quality class of the reference value. The proportion of misclassifications was calculated for selected metrics and different subsampling sizes (Table 20). The results are ambiguous. On the one hand they do not correspond to the reliability of the metrics as expressed by the deviation to the reference value (Table 17, Table 18, Table 19). Some metrics show high percentages of misclassifications in the quality class while the absolute deviation of the results to the reference value is comparatively small (e.g. German Fauna Index in stream type 9: 30.1 % misclassification for the 300-individuals subsamples; proportional deviation to the reference values: - 1.4 ± 10.7 %). For other metrics the proportion of misclassifications is comparatively small in relation to the standard deviation from the reference value (e.g. 700 individuals, stream type 15: [%] pelal preferences: misclassified 3.6 %; mean deviation: - 0.1 ± 13.4 %).

Furthermore, there are obvious differences between stream types. In the Multimetric Index EQI_M the misclassification of the 300-individuals subsamples is 21.6 % for stream type 15, while in stream type 5 it is > 30 % and in stream type 9 28.1 %. In the 700-individuals subsamples 11.3 % of the samples have been misclassified in the lowland streams (stream type 15) in contrast to about 20 % for the mountain stream types (5 and 9). Thus, the misclassification rate in the 300-individuals subsamples of stream type 15 is almost as high as the misclassification rate in the 700-individuals subsamples of stream type 5 and 9. Furthermore, 19 out of 54 samples in stream type 15 contained less than 700 organisms.

The comparatively low percentages of misclassifications calculated for the German Saprobic Index (new version) is likely due to the pre-selection of the sampling sites, which were all unpolluted or only moderately polluted. Therefore, the probability of misjudgement is limited, since species indicating organic pollution are scarcely present. Besides the German Saprobic Index certain metrics addressing the proportion of ecological traits (habitat, current, feeding types) show low deviation to the reference quality classes even in small subsamples (200-300 ind.). In contrast, the German Fauna Index and richness measures such as the number of EPTCBO-taxa reach stable results only in large subsample sizes. The formula of the German Fauna Index resembles the German Saprobic Index: abundance classes and scores of indicator taxa are transformed into a metric result. The metric was developed based on samples containing high numbers of organisms (compare Chapter 2; Lorenz et al. 2004). Consequently, the overall metric calculation depends on high numbers, restricting the reliability of smaller samples. Since the German Fauna Index contributes to 50 % of the Multimetric Index EQI_M, the misclassification of the latter is almost equally high. The main sources for misclassification of samples taken in the mountain streams are two metrics, which are abundance dependent. Regarding the bootstrap results, obvious improvements of the results are only visible for the German Fauna Index, the Multimetric Index EQI_M and the abundance dependent metrics in the mountain stream types. Although bootstrap samples underestimate the variability of taxa richness measures because the original sample has by definition the maximum number of taxa, it is obvious that abundance dependent metrics improve in their performance. Therefore, the class boundaries for the metrics contributing to the EQI_M should be set in relation to the subsample size, particularly for taxa richness measures.

In conclusion, subsampling is potentially a time and money saving method, which could lead to convincing results if at least 300 individuals are considered and if the variability of the metrics and their different sensitivity to subsampling is kept in mind.

Summary and Conclusions

The benthic invertebrate community of streams is the focus of interest in this study. The faunal assemblage is a scientific object, which can be evaluated in various different ways. I tried to concentrate on three aspects following a logical stepwise approach. The thesis starts with comparing faunal assemblages from different streams throughout Germany (compare Chapter 1.1). 390 macroinvertebrate samples of near-natural sites were used. The analysis detected and visualised faunal differences using the statistical method "Non-metric Multidimensional Scaling" (NMS). In the relevant diagrams (e.g. Figure 2) similar benthic invertebrate communities are plotted close to each other and unlike ones remote from another. Abiotic information of the sampling sites contributed as overlays to the interpretation of the results. Thus, a classification of mountain and alpine streams was performed on the basis of the benthic invertebrate community and with the help of physical information.

However, few streams or even stream reaches in Germany are in a near-natural state. Several mainly anthropogenic degradation factors have influenced German streams in different intensities, e.g. pollution by organic sewage, hydromorphological alteration by straightening for an improved land use or an assumed flood protection. Thus, an assessment method is needed for a better understanding of the reaches, where not only the assignment to a certain stream type is essential but also the knowledge about the degree of degradation. Hence, the second chapter deals with the development of an assessment system for mid-sized mountain streams. The results of Chapter 1.3 underline, that different stream types are inhabited by different macroinvertebrates; thus, a community-based assessment system should also be stream type specific. As an example mid-sized streams of lower mountainous areas were chosen for an intensive study of hydromorphological degradation indicated by the faunal assemblage. Organic pollution was not in the focus of this study, since the actual main impact factor for mountain streams in Germany is the hydromorphological alteration. Regression and correlation analysis were internal parts of this study. Several parameters describing anthropogenic alteration were correlated to functional metrics, which characterise the benthic invertebrate community. These metrics were calculated from the taxa lists extracted by the identification of standardised samples taken at 20 sampling sites in spring and summer.

Besides these well known functional metrics a new metric was developed (the German Fauna Index; compare Chapter 2), which is based on the occurrence (presence/absence) and the abundance of taxa in different degradation stages of this particular stream type. This new metric forms the heart of the assessment systems because it focuses on species and their needs for certain features and habitats.

Inherent to assessment systems are the critics about their applicability and their statistical reliability. This led to the third line of research (Chapter 3), which aims to estimate the minimum numbers of organisms, which need to be counted in a sample to obtain a valid or adequately reliable assessment result. Samples from three German stream types were investigated applying an electronic subsampling technique (see Chapter 3). Based upon the original samples (taxa lists) of the AQEM-project, 100 subsamples of 100, 200, 300, 500 and 700 individuals were generated from each sample. Each time a computer algorithm selected these organisms randomly. For the analysis, the metrics of the assessment systems of these stream types were investigated more closely. Statistical reliability was assessed by calculating standard deviations, proportional deviations and misclassifications for the metric results as well as for quality classes. The results led to clear recommendations on how many individuals are needed for valid assessment results.

Hence, the results of this thesis can be summarised as followed:

- Clear stream types throughout the entire country can be based on benthic invertebrate data, if pan German samples of different sources are analysed at a standardised taxonomic resolution.
- Four different mountain and alpine stream types can be distinguished by samples taken with diverse protocols and involving spring and summer samples.
- Ten different stream types (four mountain, two alpine and four lowland stream types, respectively) were identified using samples taken with a standardised protocol and considering only summer samples.
- Several species are not stream type specific but stream size specific and can be found in the lowlands as well as in the mountains in streams of similar size.
- Key indicator taxa are proposed for two stream types: mid-sized and large streams in lower mountainous areas.
- For typological calculations taxa lists should ideally be identified to species level, the complete benthic invertebrate community should be considered and the abundances should be log (x+1) transformed.

- The benthic invertebrate community can be used to assess the impact of hydromorphological degradation.
- A new index based on macroinvertebrates, the "German Fauna Index", has been developed to detect the impact of hydromorphological degradation in mid-sized mountain streams.
- In conjunction with the "German Fauna Index", four additional metrics are combined to the "Ecological Quality Index using Macroinvertebrates" (EQI_M), which assesses the impact of hydromorphological degradation in mid-sized mountain streams.
- Tests with an additional data set proved the applicability of the "German Fauna Index" and the "Ecological Quality Index using Macroinvertebrates" (EQI_M) in assessing mid-sized streams in lower mountainous areas.
- Minimum numbers of organisms to be counted in standardised protocols for benthic invertebrate samples are necessary and can be estimated.
- Metrics, which rely on absolute abundances or abundance classes are more sensitive to a changing number of individuals than metrics, which depend on relative abundances.
- The reliability of the metrics is related to subsample size, stream type and metric type.
- At least 300 individuals are necessary for a valid assessment result.

Deutsche Kurzfassung der Dissertation

Mittelgebirgsflüsse
-
ihre Typologie, ihre Bewertung und die Zuverlässigkeit von Besammlungs- und Bewertungsmethoden

Die vorliegende Arbeit hat drei Zielsetzungen:

1.) Validierung der Fließgewässer-Typologie Deutschlands mit Hilfe des Makrozoobenthos.
2.) Erstellung eines Bewertungssystems für den Gewässertyp „mittelgroße Flüsse des (silikatischen) Mittelgebirges" mit Hilfe des Makrozoobenthos.
3.) Tests zur Zuverlässigkeit von Bewertungssystemen und Prüfung der Mindestgröße einer Makrozoobenthosprobe.

1 Validierung der Fließgewässer-Typologie Deutschlands mit Hilfe des Makrozoobenthos

Als Typologie wird die Zuordnung von Elementen zu Gruppen aufgrund einer Ganzheit von Merkmalen bezeichnet. Im vorliegenden Fall wird die Zuordnung von Fließgewässerabschnitten zu in sich homogenen Fließgewässertypen angestrebt. Auf dieser Grundlage können dann an den jeweiligen Typ angepasste Bewertungssysteme erstellt werden (siehe 2).

Schmedtje et al. veröffentlichten 2001 eine „top-down"-Typologie für die Fließgewässer Deutschlands. Diese Liste nennt potenzielle, biozönotisch bedeutsame Fließgewässertypen, beruht aber auf abiotischen Parametern (Einzugsgebietsgröße, Sohlsubstrat, Geologie) und Expertenmeinung und nicht auf Daten zur Biozönose. Sommerhäuser & Pottgiesser (2004) ergänzten und erweiterten die Liste auf 24 Typen. In dieser Arbeit erfolgte mit Hilfe der bodenlebenden Gewässerorganismen (Makrozoobenthos) die Validierung der Mittelgebirgs- und Alpentypen nach dem „bottom-up"-Verfahren.

1.1 Typologie auf Grundlage verschiedener Probenahmeverfahren

Im Rahmen des vom Umweltbundesamt (UBA) geförderten Projektes „Weiterentwicklung und Anpassung des nationalen Bewertungssystems für Makrozoobenthos an neue internationale Vorgaben“ wurde von der Universität Hohenheim eine Datenbank erstellt, in der Makrozoobenthosproben aus dem gesamten Bundesgebiet zusammengeführt wurden. Ausgewählte Datensätze dieser Datenbank sowie eine Datenbank von Untersuchungen der Abteilung Hydrobiologie der Universität Duisburg-Essen bildeten die Basis für die anschließende statistische Auswertung. Hierzu wurden die beiden Datenbanken in einer „Typologiedatenbank“ zusammengeführt, in der sowohl Taxalisten als auch abiotische Parameter der Probestellen aufgenommen wurden.

Aufgrund der heterogenen Datenlage wurden lediglich die taxonomischen Gruppen Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Odonata und Mollusca (EPTCOM) in die Analyse einbezogen sowie deren Anwesenheit bzw. Abwesenheit in den Proben. Filterkriterien dienten dazu, diejenigen Datensätze zu selektieren, die naturnahe Verhältnisse widerspiegeln und eine vergleichbare Datenqualität aufweisen, z. B. Saprobienindex (< 2,4), Gewässerstrukturgüte (< Klasse 3), Einzugsgebietsgröße (> 8 km^2), Anzahl Gattungen der taxonomischen Gruppen EPTCOM (> 9).

390 Datensätze naturnaher Fließgewässerabschnitte bildeten nach der Filterung die Grundlage der Analyse. Diese wurden nach dem Beprobungszeitraum (Frühjahr oder Sommer) in Unterdatensätze aufgeteilt und mit Hilfe des statistischen Verfahrens „Non-metric Multidimensional Scaling“ (NMS) ausgewertet. Abiotische Parameter der Probestellen (Einzugsgebietsgröße, Geologie, Höhenlage, Ökoregion) dienten als Hilfe für die Interpretation der Ergebnisse der taxonomischen Analyse.

Als Ergebnisse auf der taxonomischen Ebene „Gattung“ lassen sich zusammenfassen:

1. Gewässer der Ökoregion 14 (Zentrales Tiefland, nach Illies 1978) trennen sich von Gewässern der Ökoregionen 4 (Alpen), 8 (Westliches Mittelgebirge) und 9 (Zentrales Mittelgebirge) deutlich ab.
2. Die Mittelgebirgs- und Alpengewässer zeigen Überlappungen.

Als Ergebnisse auf der taxonomischen Ebene „Art“ lassen sich zusammenfassen:

1. Fließgewässer der Alpen unterscheiden sich von Fließgewässern der Mittelgebirge.
2. Innerhalb der Mittelgebirgsgewässer ist ein Größengradient (Einzugsgebietsgröße) erkennbar und in geringerer Deutlichkeit eine geologische Differenzierung.

3. Gewässer mit einem Einzugsgebiet kleiner als 100 km^2 trennen sich von Gewässern mit einem Einzugsgebiet zwischen 100 und 10000 km^2.
4. Flüsse mit einem Einzugsgebiet größer als 10000 km^2 weisen eine eigenständige Fauna auf.
5. Die Ökoregionen 8 und 9 besitzen keine eigenständige Fließgewässerfauna.
6. Auf Grundlage der Geologie der Probestellen können bei Mittelgebirgsbächen (Einzugsgebietsgröße: 10 – 100 km^2) drei Subtypen unterschieden werden: silikatische Buntsandsteinbäche, silikatische Schieferbäche und karbonatische Bäche.

1.2 Taxonomische Auflösung

In dieser Untersuchung wurde anhand einheitlicher Datensätze getestet, welche Qualität Taxalisten haben sollten, um typologische Berechnungen durchführen zu können.
Als Datenbasis dienten 25 Sommerproben der Gewässertypen 9 (mittelgroße Flüsse des Mittelgebirges, Einzugsgebietsgröße: 100 – 1000 km^2; nach Sommerhäuser & Pottgiesser 2004) und 9.2 (große Flüsse des Mittelgebirges, Einzugsgebietsgröße: 1000 – 10000 km^2). Die Proben wurden von Mitarbeitern der Universität Duisburg-Essen und dem Forschungsinstitut Senckenberg mit der AQEM-Methode (Hering et al. 2004) genommen.
Bei der Analyse der Daten wurden folgende Variablen gegenübergestellt:

1. Bestimmungsniveau: Familienebene zu Artebene
2. Vollständigkeit der Artenliste: EPTCOM-Taxa zu gesamter Biozönose
3. Dichte: Anwesenheit bzw. Abwesenheit zu logarithmierten Individuendichten

Die graphische Darstellung der Ergebnisse wurde wieder mittels NMS durchgeführt, das Testen der Zugehörigkeit der Proben zu den beiden Typen mittels einer Clusteranalyse. Eine „Mean (dis)similarity Analysis" berechnete die Ähnlichkeit bzw. Unähnlichkeit der beiden Gewässertypen zueinander. Die Berechnungen wurden mit dem PC Programm „PC-ORD 4.27" (McCune & Mefford 1999) bzw. „Meansim6" (Van Sickle 1997) durchgeführt.

Als Ergebnisse lassen sich zusammenfassen:

1. Die Artebene in Kombination mit der gesamten Biozönose mit logarithmierten Individuendichten ergibt die deutlichste Trennung der beiden Gewässertypen.
2. Die Artebene spaltet beide Typen deutlicher auf als die Familienebene.

3. Der „Stress" (als Maß für die Übereinstimmung der graphischen Wiedergabe mit dem errechneten Ergebnis) ist geringer (somit besser), wenn die gesamte Biozönose mit logarithmierten Abundanzen herangezogen wird.
4. Die taxonomischen Gruppen EPTCOM in Kombination mit Anwesenheit bzw. Abwesenheit erbringen eine entsprechende Trennung wie unter Punkt 1. dargestellt, dies jedoch in leicht abgeschwächter Form.
5. Die Familienebene sollte für typologische Berechnungen nicht verwendet werden, da die Abtrennung schwächer ausfällt als auf Artebene.

1.3 Typologie auf Grundlage eines einheitlichen Probenahmeverfahrens

Mögliche Kritikpunkte an der Validierung der Typologie (Kapitel 1.1) sind die uneinheitliche Probenahme, die Reduzierung der Datensätze auf die taxonomischen Gruppen EPTCOM und die Verwendung von Daten, die lediglich Anwesenheit bzw. Abwesenheit der Taxa angeben. Diese zugrunde gelegten Kriterien stellten letztlich einen Kompromiss dar, um aus der heterogenen Datenlage ein Maximum an vergleichbaren Informationen herauszuholen.

Kapitel 1.2 beweist, dass das Artniveau und Daten zur Anwesenheit bzw. Abwesenheit wissenschaftlich nachvollziehbare Ergebnisse erbringen. Eine Verwendung der gesamten Biozönose inklusive Abundanzen würde eine schärfere Trennung der Gewässertypen ergeben, aber keine prinzipiell neuen Erkenntnisse.

Im Folgenden wurde die Methodendiskussion behandelt, wobei auch der Frage nachgegangen wurde, ob die einzelnen Typen sowohl validiert als auch weiter aufgegliedert werden können.

Verschiedene Projekte der letzten Jahre (AQEM [5], STAR [6], LAWA-[7], UBA-Projekt [8]) basierten auf einer einheitlichen (standardisierten) Probenahme (AQEM-Methode) sowie einer hohen

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[5] The Development and Testing of an Integrated **A**ssessment System for the Ecological **Q**uality of Streams and Rivers throughout **E**urope using Benthic **M**acroinvertebrates (AQEM wurde gefördert durch die Europäische Union, 5. Rahmenprogramm, Energie, Umwelt und nachhaltige Entwicklung, Key Action 1 "Sustainable Management and Quality of Water", Förderkennzeichen: EVK1-CT1999-00027).

[6] **Sta**ndardisation of **R**iver Classifications: Framework method for calibrating different biological survey results against ecological quality classifications to be developed for the Water Framework Directive (STAR wird gefördert durch die Europäische Union, 5. Rahmenprogramm, Energie, Umwelt und nachhaltige Entwicklung, Key Action 1 "Sustainable Management and Quality of Water", Förderkennzeichen: EVK1-CT2001-00089).

[7] „Validation der Fließgewässertypologie Deutschlands" (dieses Projekt wurde gefördert durch die Länderarbeitsgemeinschaft Wasser)

[8] „Weiterentwicklung und Anpassung des nationalen Bewertungssystems für Makrozoobenthos an neue internationale Vorgaben" (dieses Projekt wurde gefördert durch das Umweltbundesamt)

Bestimmungsqualität der Proben. Taxalisten von Proben, die an naturnahen Abschnitten genommen wurden, können somit für eine erweiterte Prüfung der Typologie herangezogen werden.
Hierzu wurden 67 Gewässer aus verschiedensten Regionen Deutschlands, die jeweils im Sommer beprobt wurden, mit Hilfe von Filterkriterien (Gewässertypspezifischer Saprobienindex < Klasse 3; Einzugsgebietsgröße > 8 km^2; morphologische und ökologische Einschätzung durch den Probenehmer sehr gut oder gut) als „naturnah" eingestuft und gingen in die Analyse ein. Als Analysemethode wurde das NMS-Verfahren gewählt, wobei die abiotischen Parameter Ökoregion, Höhenlage, Geologie, Größe des Einzugsgebietes, Artenzahl, Typeinstufung nach Sommerhäuser & Pottgiesser (2004) sowie die Ergebnisse einer Clusteranalyse als erklärende Faktoren für das Gesamtergebnis dienten.

Als Ergebnisse lassen sich zusammenfassen:

1. Zehn Gewässertypen können unterschieden werden.
2. Entscheidende Gradienten bei der Auftrennung der Proben in Gewässertypen sind: Höhenlage, Talgefälle, Artenzahl und Einzugsgebietsgröße.
3. Tiefland, Mittelgebirge und Alpen haben eigenständige Gewässertypen.
4. Fließgewässer der Hochalpen (> 800 m) unterschieden sich von Fließgewässern der niedrigeren Alpenregionen (< 800 m).
5. Buntsandsteinbäche trennen sich von Schieferbächen im Mittelgebirge.
6. Mittelgroße Flüsse des Mittelgebirges (Einzugsgebietsgröße: 100 – 1000 km^2) lassen sich von großen Flüssen des Mittelgebirges (Einzugsgebietsgröße: 1000 – 10000 km^2) abgrenzen.
7. Die Typgrenzen liegen im Tiefland bei den Einzugsgebietsgrößen: 200 km^2, 1000 km^2, 10000 km^2.
8. Der Grundwassereinfluss und somit die Wassertemperatur spielt im Tiefland ein große Rolle bei der Zonierung, welche ausschlaggebend für den Typ ist.

1.4 Schlüsselarten mittelgroßer und großer Flüsse des Mittelgebirges

Nach der Analyse der gesamtbiozönotischen Unterschiede von Fließgewässern wurde mit einer weiteren Untersuchung ins Detail gegangen. Die Biozönosen naturnaher Probestellen an mittelgroßen Flüssen (Einzugsgebietsgröße: 100 – 1000 km^2) und großen Flüssen (Einzugsgebietsgröße: 1000 – 10000 km^2) des Mittelgebirges wurden auf Artniveau analysiert, um einerseits Unterschiede und Gemeinsamkeiten innerhalb der Fauna

herauszufinden und um andererseits Schlüsselarten aus den Datensätzen zu extrahieren. Durch einen Abgleich weiterer Taxalisten mit den ermittelten Schlüsselarten kann dann die Zugehörigkeit einer Probestelle zu einem Gewässertyp und aufgrund von Abweichungen von der Zusammensetzung der Schlüsselarten die Degradation einer Stelle ermittelt werden.
25 Sommerproben (siehe auch Kapitel 1.2) dienten als Datengrundlage dieser Analyse der Schlüsselarten. Das Programm „IndVal" (Indicator value analysis; Dufrêne & Legendre 1997) aus dem Software-Paket „PC-ORD 4.27" wurde zur Analyse der Taxalisten verwendet.

Als Ergebnisse lassen sich zusammenfassen:

1. Beide Gewässertypen trennen sich aufgrund der Arten des Makrozoobenthos deutlich von einander ab.
2. Mittelgroße Flüsse sind von einer Steinfliegenfauna hoher Diversität besiedelt.
3. In den Hauptgruppen Ephemeroptera, Coleoptera, Trichoptera und Mollusca finden sich jeweils Schlüsselarten für beide Gewässertypen.
4. Schlüsseltaxa der mittelgroßen Flüsse des Mittelgebirges sind *Sericostoma* sp., *Leuctra geniculata, Ancylus fluviatilis, Ecdyonurus venosus*-Gr., *Baetis scambus, Hydraena gracilis*.
5. Schlüsseltaxa der großen Flüsse des Mittelgebirges sind *Aphelocheirus aestivalis, Baetis fuscatus, Pisidium* sp., *Heptagenia sulphurea, Psychomyia pusilla, Brachycentrus subnubilus* und *Stenelmis canaliculata*.
6. Aufgrund der distinkten Fauna beider Typen können Bewertungssysteme auf diese Schlüsselarten aufgebaut werden.

2 Erstellung eines Bewertungssystems für den Gewässertyp „mittelgroße Flüsse des (silikatischen) Mittelgebirges“ mit Hilfe des Makrozoobenthos

Als Bewertung wird die Einstufung der Qualität eines Objektes im Vergleich mit einem Referenzzustand bezeichnet. In diesem Fall betrifft es die Bewertung der ökologischen Qualität von Fließgewässerabschnitten.

Im Rahmen des AQEM-Projektes (www.aqem.de) wurde unter anderem der Gewässertyp „mittelgroße Flüsse des (silikatischen) Mittelgebirges“ untersucht.

An 20 Probestellen wurden im Frühjahr und Sommer 2000 Makrozoobenthosproben nach einer standardisierten Methode (AQEM-Methode; Hering et al. 2004) genommen. Des Weiteren wurden ca. 200 abiotische Parameter zur Hydromorphologie und zur Situation im Einzugsgebiet der Probestellen mit Hilfe eines einheitlichen Protokolls (Hering et al. 2004) aufgenommen. Die Auswahl der 20 Untersuchungsstellen erfolgte aufgrund hydromorphologischer Unterschiede, wobei die Stellen in fünf Degradationsklassen voreingestuft wurden.

Nach der taxonomischen Bestimmung der Makrozoobenthosproben dienten diese der Erstellung eines Bewertungssystems für die strukturelle Degradation der Abschnitte. Die Entwicklung des Bewertungssystems erfolgte in drei Schritten:

1. Berechnung bekannter Metriks und Auswahl derjenigen, die mit hydromorphologischer Degradation korrelieren.
2. Entwicklung eines neuen Index („German Fauna Index“).
3. Kombination der ausgewählten Metriks und des „German Fauna Index“ zu einem multimetrischen Index.

Biotische „Metriks“ sind Maßzahlen, die auf der Anwesenheit bzw. Abwesenheit und/oder Häufigkeit von Taxa und deren autökologischen Präferenzen beruhen. Abiotische Parameter des Protokolls wurden parallel zu einem „Strukturindex“ vereinigt, der die Degradation der Hydromorphologie anzeigt. Anhand von Korrelationen gegen diesen Index wurden geeignete Metriks, die eine strukturelle Degradation der Probestellen nachzeichnen, ermittelt. Metriks, die positiv oder negativ mit dem „Strukturindex“ korrelierten und deren Zusammenhang mit der Struktur kausal nachvollziehbar war, wurden als Schlüsselmetriks ausgewählt.

Die Anwesenheit bzw. Abwesenheit und Häufigkeit der Taxa an Stellen verschiedener Degradationsklassen diente als Berechnungsmatrix für einen neuen Index. Taxa, die an Stellen mit naturnaher Morphologie vorkamen, wurden mit einem positiven Indikatorwert (+1 oder +2) versehen. Taxa, die an morphologisch degradierten Stellen gefunden wurden, erhielten negative Indikatorwerte (–1 oder –2). Die Ermittlung der Indikatorwerte erfolgte

mittels des Programmes „IndVal" (Dufrêne & Legendre 1997) sowie einer Literaturstudie, die auf die Habitatansprüche der gefundenen Arten abzielte. Die Berechnung des „German Fauna Index" entspricht der Gleichung des Saprobienindex (DEV 1992), enthält aber keine Gewichtungsfaktoren. Die Individuenzahl jeder Art wird zunächst in eine Abundanzklasse umgewandelt und mit dem jeweiligen Indikatorwert multipliziert. Diese Produkte werden summiert und durch die Summe der Abundanzklassen geteilt.
Um zur Endbewertung zu gelangen wurden die Ergebnisse der einzelnen Metriks in fünf Qualitätsklassen umgewandelt, von denen dann der Mittelwert die Gesamtbewertung des Abschnittes darstellt. Der „German Fauna Index" trägt hierbei zu 50 % zur Gesamtbewertung bei.

Als Ergebnisse lassen sich zusammenfassen:

1. Die Auswirkungen hydromorphologischer Degradation sind mit Hilfe des Makrozoobenthos ermittelbar.
2. Ein neuer Index, der „German Fauna Index", wurde entwickelt, um Auswirkungen hydromorphologischer Degradation anzuzeigen. 155 Taxa erhielten Indikatorwerte (–2; –1; +1; +2), die auf Grundlage ihrer ökologischen Ansprüche vergeben wurden.
3. Vier weitere Metriks (Summe des Prozentanteils der Akal-, Lithal- und Psammalbesiedler; Anzahl EPTCBO-Taxa; Shannon-Wiener-Diversität; Summe des Prozentanteils der Holzfresser, Zerkleinerer, sowie der aktiven und passiven Filtrierer) korrelieren mit der hydromorphologischen Degradation.
4. Die Kombination aus den fünf Metriks (inklusive dem „German Fauna Index") dient der Bewertung der Auswirkungen hydromorphologischer Degradation von mittelgroßen Flüssen des Mittelgebirges, wobei der „German Fauna Index" 50 % des Ergebnisses ausmacht.

3 Tests zur Zuverlässigkeit von Bewertungssystemen und Prüfung der Mindestgröße einer Makrozoobenthosprobe

Nach der Erstellung der Bewertungssysteme im AQEM-Projekt wurde die statistischen Robustheit getestet. Untersucht wurden alle Metriks, die mit der AQEM-Software berechnet werden und somit teilweise in einem der Bewertungssysteme für folgende Fließgewässertypen enthalten sind: mittelgroße Sandflüsse im Norddeutschen Tiefland, Bäche des Mittelgebirges und mittelgroße Flüsse des Mittelgebirges.

Der Einfluss der Probengröße auf das Ergebnis der einzelnen Metriks und auf die Gesamtbewertung wurde kontrolliert, wobei die Taxalisten des AQEM-Projektes die Grundlage bildeten. Jede dieser Listen diente als Grundgesamtheit, aus der computergestützt und per Zufallsgenerator Unterproben (d. h. Teillisten) mit geringeren Individuenzahlen (und damit auch geringeren Taxazahlen) erzeugt wurden. Aus jeder der 152 Taxalisten wurden 100 Unterproben mit jeweils 100, 200, 300, 500 und 700 Individuen gezogen. Die Unterproben („Subsamples") wurden anschließend in die jeweiligen Bewertungssysteme in der AQEM-Software eingelesen. Die sich ergebenden Abweichungen in den Ergebnissen der einzelnen Metriks zur Originalprobe stellen ein Maß für die Robustheit der Metriks dar.

Für eine Gesamtbewertung der Auswirkungen hydromorphologischer Degradation und der Saprobie wurden die Ergebnisse ausgewählter Metriks in Qualitätsklassen umgewandelt (siehe Kapitel 2). Die Fehleinstufung dieser Metriks im Vergleich zur Originalprobe wurde für alle Unterproben berechnet, um auf diese Weise die Robustheit der Gesamtbewertung zu testen.

Als Ergebnisse lassen sich zusammenfassen:

1. Mit abnehmender Unterprobengröße (Anzahl an Individuen) erhöht sich die Abweichung zur Originalprobe.
2. Die einzelnen Metriks zeigen eine unterschiedliche Sensitivität bei abnehmender Unterprobengröße.
3. Mehr als 40 % aller Unterproben mit 100 Individuen wurden in eine andere Qualitätsklasse eingestuft als die Originalprobe. Bei den Unterproben mit 700 Individuen waren dies weniger als 20 %.
4. Die Fehleinstufung bei den mittelgroßen Tieflandflüssen erreicht bei den Unterproben mit 300 Individuen die 20 %-Grenze; bei den Bächen und mittelgroßen Flüssen des Mittelgebirges wird diese Grenze erst bei 700 Individuen pro Probe erreicht.
5. Metriks, die auf absoluten Abundanzen oder Abundanzklassen beruhen (z. B. BMWP, Anzahl Taxa) zeigen eine höhere Sensitivität zu einer verringerten Individuenzahl als

Metriks, die auf relativen Abundanzen beruhen (z. B. Prozentanteil Lithalbesiedler, Prozentanteil Zerkleinerer).

6. Die Robustheit und damit die Stabilität der Metriks ist abhängig von der Unterprobengröße, dem Gewässertyp und dem Metriktyp.

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Appendices

Appendix 1. Table of the biocoenotically significant stream types of Germany for the ecological quality element macroinvertebrates according to Sommerhäuser & Pottgiesser (2004) on the basis of Schmedtje et al. (2001). [„Biozönotisch bedeutsame Fließgewässertypen Deutschlands – Qualitätskomponente Makrozoobenthos"]

Ausgewählte Gewässerlandschaften und Regionen nach Briem (2001)	Biozönotischer Typ			
	Längszonierung			
	Bach	Kl. Fluss	Gr. Fluss	Strom
Ökoregion 4: Alpen, Höhe > 800 m				
Kalkalpen, Flyschzone	1[9]			
Ökoregion 9 (und 8): Mittelgebirge und Alpenvorland, Höhe ca. 200 - 800 m und höher				
Alpenvorland				
Tertiäres Hügelland, Niederterrassen, Ältere Terrassen, Altmoränenland	2[10]		4	
Jungmoränenland	3[11]			
Auen (über 300 m Breite)				
Mittelgebirge				
Gneis, Granit, Schiefer, übrige Vulkangebiete	5	9	9.2	
Buntsandstein, Sandbedeckung	5.1			
Lössregionen, Keuper, Kreide	6	9.1		
Muschelkalk, Jura, Malm, Lias, Dogger, Kalke	7			
Auen (über 300 m)				10
Ökoregion 14: Norddeutsches Tiefland, Höhe < 200 m				
Sander, Sandbedeckung, Grund- und Endmoräne	14	15		
Lössregionen	18			
Grund- und Endmoräne, Ältere Terrassen	16	17		
Auen (über 300 m)				20
Marschen	22[12]			
Jungmoränenland: Grundmoränen	23			
Ökoregion unabhängige Typen				
Sander, Lössregionen, Auen (vermoort)	11	12		
Auen (über 300 m)	19			
Sander, Grund- und Endmoräne	21			

9 Differenzierung in Subtypen 1.1 „Bäche und kleine Flüsse der Kalkalpen" sowie Subtyp 1.2 „Große Flüsse der Kalkalpen"
10 Differenzierung in Subtyp 2.1 „Bäche des Alpenvorlandes" sowie Subtyp 2.2 „Kleine Flüsse des Alpenvorlandes"
11 Differenzierung in Subtyp 3.1 „Bäche der Jungmoräne des Alpenvorlandes" sowie Subtyp 3.2 „Kleine Flüsse der Jungmoräne des Alpenvorlandes"
12 Die Typen-Differenzierung ist noch nicht abgeschlossen.

Appendix 2. Stream type number, German short names and English names for the biocoenotically significant stream types of Germany on the basis of Schmedtje et al. (2001)and Sommerhäuser & Pottgiesser (2004) (unpublished). (n.d. = not yet defined)

Stream type number	German short name	English name
1[13]	Fließgewässer der Alpen	Alpine streams
2[14]	Fließgewässer des Alpenvorlandes	Streams in the alpine foothills
3[15]	Fließgewässer der Jungmoräne des Alpenvorlandes	Streams in the Pleistocene sediments of the alpine foothills
4	Große Flüsse des Alpenvorlandes	Large streams in the alpine foothills
5	Grobmaterialreiche, silikatische Mittelgebirgsbäche	Small (siliceous cobble bottom) streams in lower mountainous areas
5.1	Feinmaterialreiche, silikatische Mittelgebirgsbäche	Small siliceous sandstone streams in lower mountainous areas
6	Feinmaterialreiche, karbonatische Mittelgebirgsbäche	Small loam/sand bottom streams (dominated by fine sediments) in calcareous lower mountainous areas
7	Grobmaterialreiche, karbonatische Mittelgebirgsbäche	Small (cobble bottom) streams in calcareous lower mountainous areas
9	Silikatische, fein- bis grobmaterialreiche Mittelgebirgsflüsse	Mid-sized (siliceous cobble/boulder bottom) streams in lower mountainous areas
9.1	Karbonatische, fein- bis grobmaterialreiche Mittelgebirgsflüsse	Mid-sized streams in calcareous lower mountainous areas (different substrate)
9.2	Große Flüsse des Mittelgebirges	Large cobble/boulder bottom streams in lower mountainous areas
10	Kiesgeprägte Ströme	Large cobble bottom rivers
11	Organisch geprägte Bäche	Small streams with organic substrates
12	Organisch geprägte Flüsse	Mid-sized streams with organic substrates
14	Sandgeprägte Tieflandbäche	Small sand bottom streams in the lowlands
15	Sand- und lehmgeprägte Tieflandflüsse	Mid-sized to large sand bottom streams in the lowlands
16	Kiesgeprägte Tieflandbäche	Small gravel bottom streams in the lowlands
17	Kiesgeprägte Tieflandflüsse	Mid-sized to large gravel bottom streams in the lowlands
18	Löss-lehmgeprägte Tieflandbäche	Clay/loam bottom streams in the lowlands
19	Kleine Niederungsfließgewässer in Fluss- und Stromtälern	Small streams in floodplains
20	Sandgeprägte Ströme	Large sand bottom rivers
21	Seeausflussgeprägte Fließgewässer	n.d.
22[16]	Marschengewässer	n.d.
23	Rückstau- bzw. brackwasserbeeinflusste Ostseezuflüsse	n.d.

[13] Partitioning in subtyp 1.1 "small and mid-sized streams in the limestone Alps" („Bäche und kleine Flüsse der Kalkalpen") and subtyp 1.2 "large streams in the limestone Alps" („Große Flüsse der Kalkalpen".

[14] Partitioning in subtyp 2.1 "small streams in the alpine foothills" („Bäche des Alpenvorlandes") and subtyp 2.2 "mid-sized streams in the alpine foothills" („Kleine Flüsse des Alpenvorlandes").

[15] Partitioning in subtyp 3.1 "small streams in the pleistocene sediments of the alpine foothills" („Bäche der Jungmoräne des Alpenvorlandes") and subtyp 3.2 "mid-sized streams in the pleistocene sediments of the alpine foothills" („Kleine Flüsse der Jungmoräne des Alpenvorlandes").

[16] The partitioning of types is not yet completed.

Appendix 3. List of scores of indicator taxa for the mid-sized streams in lower mountainous areas of Germany; "Ref.": references, from which the index values were derived. (Bi = Bivalvia; Co = Coleoptera; Cr = Crustacea; Di = Diptera; Ep = Ephemeroptera; Ga = Gastropoda; He = Heteroptera; Hi = Hirudinea; Me = Megaloptera; Od = Odonata; Ol = Oligochaeta; Pl = Plecoptera; Tc = Trichoptera; Tu = Turbellaria; A = IndVal analyses with the AQEM data; B = LUA NRW 1999a, 1999b, 2000, 2001; C = habitat or current preferences taken from Schmedtje & Colling 1996; D = feeding types or longitudinal zonation preferences taken from Moog 1995; X = expert judgement)

Group	Taxon name	Author	Score	Ref.
Ga	Gyraulus albus	(O.F. MÜLLER, 1774)	-2	A
Ga	Gyraulus sp.		-2	A
Ga	Potamopyrgus antipodarum	(GRAY, 1843)	-2	A
Ga	Potamopyrgus sp.		-2	A
Ga	Radix auricularia	(LINNAEUS, 1758)	-2	A
Ga	Radix balthica	(LINNAEUS, 1758)	-2	A, C
Ga	Radix balthica/labiata		-2	A, C
Ga	Radix labiata	(ROSSMÄSSLER, 1835)	-2	A, C
Ga	Radix sp.		-2	A, C
Bi	Anodonta anatina	(LINNAEUS, 1758)	1	B
Bi	Dreissena polymorpha	(PALLAS, 1771)	-2	C, X
Bi	Pisidium sp.		2	A
Bi	Sphaerium sp.		1	A
Bi	Unio crassus crassus	PHILIPSSON, 1788	2	B
Ol	Naididae Gen. sp.		-2	A, C
Ol	Tubificidae Gen. sp.		-1	A
Hi	Erpobdella nigricollis	(BRANDES, 1900)	-2	A, C
Hi	Erpobdella octoculata	(LINNAEUS, 1758)	-2	A, C
Hi	Erpobdella sp.		-2	A, C
Hi	Erpobdella testacea	(SAVIGNY, 1822)	-2	A, C
Hi	Erpobdella vilnensis	(LISKIEWICZ, 1925)	-2	A, C
Hi	Erpobdellidae Gen. sp.		-2	A
Hi	Helobdella stagnalis	(LINNAEUS, 1758)	-2	A, C
Cr	Asellus aquaticus	(LINNAEUS, 1758)	-2	A, C
Cr	Gammarus fossarum	KOCH in PANZER, 1836	2	A
Cr	Gammarus pulex	(LINNAEUS, 1758)	1	A
Ep	Baetis fuscatus	(LINNAEUS, 1761)	1	B
Ep	Baetis lutheri	MÜLLER-LIEBENAU, 1967	2	A, B
Ep	Baetis vardarensis	IKONOMOV, 1962	2	B
Ep	Caenis beskidensis	SOWA, 1973	1	A
Ep	Caenis luctuosa	(BURMEISTER, 1839)	1	A
Ep	Caenis macrura	STEPHENS, 1835	2	A, B
Ep	Caenis pseudorivulorum	KEFFERMÜLLER, 1960	2	A, B
Ep	Caenis rivulorum	EATON, 1884	1	A, B
Ep	Ecdyonurus insignis	(EATON, 1870)	2	B
Ep	Ecdyonurus macani	THOMAS & SOWA, 1970	2	A, B
Ep	Ecdyonurus venosus	(FABRICIUS, 1775)	-1	A
Ep	Epeorus sylvicola	(PICTET, 1865)	2	A, B
Ep	Ephemera danica	MÜLLER, 1764	1	A, B
Ep	Habrophlebia lauta	EATON, 1884	1	A
Ep	Heptagenia sulphurea	(MÜLLER, 1776)	1	A

Group	Taxon name	Author	Score	Ref.
Ep	Oligoneuriella rhenana	(IMHOFF, 1852)	2	B
Ep	Potamanthus luteus	(LINNAEUS, 1767)	2	B
Ep	Rhithrogena hercynia	LANDA, 1969	2	A
Ep	Siphlonurus aestivalis	(EATON, 1903)	2	B
Ep	Siphlonurus lacustris	(EATON, 1870)	2	B
Od	Calopteryx splendens	(HARRIS, 1782)	1	B
Od	Calopteryx virgo	(LINNAEUS, 1758)	1	B
Od	Gomphus vulgatissimus	(LINNAEUS, 1758)	1	B
Od	Onychogomphus forcipatus	(LINNAEUS, 1758)	2	B
Od	Ophiogomphus cecilia	(FOURCROY, 1785)	2	A
Pl	Amphinemura sp.		1	A, B
Pl	Brachyptera monilicornis	(PICTET, 1841)	2	B
Pl	Isoperla sp.		1	A, B
Pl	Leuctra geniculata	(STEPHENS, 1836)	1	A, B
Pl	Nemoura sp.		1	A
Pl	Perla burmeisteriana	CLAASSEN, 1936	2	A, B
Pl	Perla marginata	(PANZER, 1799)	2	A, B
Pl	Perlodes microcephalus	(PICTET, 1833)	1	B
Pl	Protonemura sp.		1	A
He	Aphelocheirus aestivalis	(FABRICIUS, 1794)	1	X
Me	Sialis fuliginosa	PICTET, 1836	-2	A
Me	Sialis lutaria	(LINNAEUS, 1758)	-2	A
Me	Sialis nigripes	PICTET, 1865	-2	A
Co	Brychius elevatus Ad.	(PANZER, 1794)	-1	A
Co	Brychius elevatus Lv.	(PANZER, 1794)	-1	A
Co	Dryops sp. Ad.		2	A
Co	Dryops sp. Lv.		2	A
Co	Elmis aenea/maugetii Ad.		1	A, B
Co	Elmis rioloides Ad.	KUWERT, 1890	1	A
Co	Elmis sp. Lv.		1	A
Co	Esolus angustatus Ad.	(MÜLLER, 1821)	-1	A
Co	Esolus angustatus Lv.	(MÜLLER, 1821)	-1	A
Co	Esolus parallelepipedus Ad.	(MÜLLER, 1806)	2	A, B
Co	Esolus parallelepipedus Lv.	(MÜLLER, 1806)	2	A, B
Co	Haliplus sp. Ad.		-2	A, C
Co	Haliplus sp. Lv.		-2	A, C
Co	Hydraena dentipes Ad.	GERMAR, 1844	1	A
Co	Hydraena gracilis Ad.	GERMAR, 1824	1	B
Co	Hydraena reyi Ad.	KUWERT, 1888	2	A
Co	Hydraena sp. Ad.		1	X
Co	Hydraena sp. Lv.		1	X
Co	Laccophilus hyalinus Ad.	(DE GEER, 1774)	1	X
Co	Laccophilus hyalinus Lv.	(DE GEER, 1774)	1	X
Co	Limnius opacus Ad.	MÜLLER, 1806	2	A, D
Co	Limnius opacus Lv.	MÜLLER, 1806	2	A, D
Co	Limnius volckmari Ad.	(PANZER, 1793)	1	A, B
Co	Limnius volckmari Lv.	(PANZER, 1793)	1	A, B
Co	Nebrioporus depressus Ad.	(FABRICIUS, 1775)	-2	A
Co	Nebrioporus depressus/elegans Ad.		-2	A
Co	Nebrioporus depressus/elegans Lv.		-2	A

Group	Taxon name	Author	Score	Ref.
Co	Nebrioporus elegans Ad.	(PANZER, 1794)	-2	A
Co	Nebrioporus sp. Ad.		-2	A
Co	Nebrioporus sp. Lv.		-2	A
Co	Orectochilus villosus Ad.	(MÜLLER, 1776)	1	A, B
Co	Orectochilus villosus Lv.	(MÜLLER, 1776)	1	A, B
Co	Stenelmis canaliculata Ad.	(GYLLENHÅL, 1808)	2	A, B
Co	Stenelmis canaliculata Lv.	(GYLLENHÅL, 1808)	2	A, B
Tc	Agapetus fuscipes	CURTIS, 1834	1	A
Tc	Agapetus ochripes	CURTIS, 1834	1	A, B
Tc	Allogamus auricollis	(PICTET, 1834)	1	A, B
Tc	Anabolia nervosa	(CURTIS, 1834)	1	A
Tc	Annitella obscurata	(McLACHLAN, 1876)	2	A
Tc	Anomalopterygella chauviniana	(STEIN, 1874)	2	A, B
Tc	Athripsodes albifrons	(LINNAEUS, 1758)	1	A
Tc	Athripsodes bilineatus	(LINNAEUS, 1758)	-1	A
Tc	Athripsodes cinereus	(CURTIS, 1834)	1	A
Tc	Brachycentrus maculatus	(FOURCROY, 1785)	1	B
Tc	Brachycentrus subnubilus	CURTIS, 1834	2	A
Tc	Ceraclea annulicornis	(STEPHENS, 1836)	1	A
Tc	Ceraclea riparia	(ALBARDA, 1874)	2	B
Tc	Chaetopteryx villosa	(FABRICIUS, 1789)	1	A
Tc	Cheumatopsyche lepida	(PICTET, 1834)	2	A, B
Tc	Chimarra marginata	(LINNAEUS, 1767)	2	A
Tc	Glyphotaelius pellucidus	(RETZIUS, 1783)	1	X
Tc	Hydropsyche dinarica	MARINKOVIC, 1979	1	A
Tc	Hydropsyche instabilis	(CURTIS, 1834)	2	A
Tc	Hydroptila sp.		-1	X
Tc	Ithytrichia lamellaris	EATON, 1873	2	X
Tc	Lasiocephala basalis	(KOLENATI, 1848)	1	A, B
Tc	Lype phaeopa	(STEPHENS, 1936)	2	B
Tc	Lype reducta	(HAGEN, 1868)	2	B
Tc	Lype sp.		2	X
Tc	Melampophylax mucoreus	(HAGEN, 1861)	1	X
Tc	Micrasema longulum	McLACHLAN, 1876	2	A, B
Tc	Micrasema minimum	McLACHLAN, 1876	1	A, B
Tc	Micrasema setiferum	(PICTET, 1834)	1	B
Tc	Mystacides azurea	(LINNAEUS, 1761)	-1	A, C
Tc	Mystacides longicornis	(LINNAEUS, 1758)	-1	A, C
Tc	Mystacides longicornis/nigra		-1	A, C
Tc	Mystacides nigra	(LINNAEUS, 1758)	-1	A, C
Tc	Mystacides sp.		-1	A, C
Tc	Odontocerum albicorne	(SCOPOLI, 1763)	1	A
Tc	Oecetis notata	(RAMBUR, 1842)	1	A
Tc	Oecetis testacea	(CURTIS, 1834)	1	A
Tc	Potamophylax latipennis	(CURTIS, 1834)	-1	X
Tc	Psychomyia pusilla	(FABRICIUS, 1781)	-1	X
Tc	Setodes punctatus	(FABRICIUS, 1793)	2	B
Tc	Silo piceus	(BRAUER, 1857)	1	A, B
Tc	Tinodes waeneri	(LINNAEUS, 1758)	-2	A
Di	Blephariceridae Gen. sp.		1	A

Group	Taxon name	Author	Score	Ref.
Di	Ibisia marginata	(FABRICIUS, 1781)	1	A
Di	Liponeura brevirostris/decipiens/vimmeri		1	A
Di	Liponeura cinerascens cinerascens	LOEW, 1844	1	A
Di	Liponeura sp.		1	A
Di	Pedicia sp.		-1	A
Di	Prosimulium hirtipes	(FRIES, 1824)	1	A, B
Di	Prosimulium tomosvaryi	(ENDERLEIN, 1921)	1	B
Di	Rhagionidae Gen. sp.		-1	X
Di	Simulium costatum	FRIEDERICHS, 1920	-1	A
Di	Simulium ornatum	MEIGEN, 1818	-1	A
Di	Simulium ornatum-Gr.		-1	A
Di	Simulium paramorsitans	RUBZOV, 1956	2	A
Di	Tipula maxima	PODA, 1761	-2	A
Di	Tipula maxima-Gr.		-2	A
Number of indicator taxa			155	
Positive indicator taxa			102	
Negative indicator taxa			53	

Appendix 4. Depth and current parameters of the spring and summer samples of the mid-sized streams in lower mountainous areas of Germany; for site codes compare Table 11. (the last number in the site code represents the season: 1 = spring, 2 = summer)

Site code	Mean depth [cm]	Maximum depth [cm]	Mean current velocity [m/s]	Maximum current velocity [m/s]
D0500011	58.1	75	0.79	1.40
D0500012	27.5	45	0.38	1.28
D0500021	30.5	45	0.84	1.80
D0500022	27.0	50	0.37	0.97
D0500031	58.0	70	0.87	1.25
D0500032	42.5	60	0.66	0.91
D0500041	51.8	70	0.95	1.35
D0500042	40.3	65	0.85	1.18
D0500051	60.0	95	0.74	1.65
D0500052	27.5	55	0.51	1.02
D0500061	50.5	90	0.41	1.12
D0500062	47.0	65	0.49	0.94
D0500071	50.8	70	0.70	1.43
D0500072	38.8	60	0.73	1.31
D0500081	23.5	65	0.59	1.33
D0500082	24.3	45	0.55	1.34
D0500091	40.4	75	0.89	1.65
D0500092	26.3	65	0.65	1.26
D0500101	53.0	70	0.91	1.20
D0500102	22.3	30	0.53	0.98
D0500111	47.5	80	0.01	0.16
D0500112	36.0	70	0.01	0.05
D0500121	41.3	60	0.84	1.14
D0500122	18.8	25	0.20	0.55
D0500131	64.3	80	0.40	0.57
D0500132	41.3	55	0.12	0.19
D0500141	43.5	55	0.86	1.24
D0500142	20.0	40	0.40	0.70
D0500151	48.5	70	0.96	1.35
D0500152	25.8	50	0.45	1.26
D0500161	54.0	80	0.85	1.60
D0500162	26.0	45	0.47	0.98
D0500171	34.0	55	0.72	1.17
D0500172	23.0	40	0.27	0.64
D0500181	36.8	60	0.66	0.96
D0500182	25.3	60	0.30	0.60
D0500191	56.3	90	0.14	0.21
D0500192	60.8	90	0.01	0.17
D0500201	55.5	80	0.84	1.15
D0500202	34.2	55	0.72	1.31

Appendix 5. Physico-chemical parameters of the spring and summer samples of the mid-sized streams in lower mountainous areas of Germany; for site codes compare Table 11. (the last number in the site code represents the season: 1 = spring, 2 = summer; n.d. = no data)

Site code	pH-value	Conductivity [µS/cm]	Dissolved oxygen content [mg/l]	Oxygen saturation [%]	BOD_5 [mg/l]	Alkalinity [mmol/l]	Total hardness [mmol/l]	Chloride [mg/l]	Ammonium [mg/l]	Nitrite [mg/l]	Nitrate [mg/l]	Ortho-phosphate [µg/l]	Total phosphate [µg/l]
D0500011	7.3	91	12.9	107.0	n.d.	n.d.	0.34	18	0.12	0.01	7.65	n.d.	31.0
D0500012	7.4	129	11.6	118.0	2.03	0.27	0.50	22	0.03	0.01	9.52	48.2	74.6
D0500021	7.0	121	11.3	105.0	n.d.	n.d.	0.26	17	0.14	0.02	6.97	56.0	38.0
D0500022	7.7	121	11.3	105.0	1.34	0.27	0.42	22	0.02	0.02	10.31	52.2	85.6
D0500031	7.9	288	11.6	102.0	4.19	n.d.	1.12	24	0.05	0.03	11.24	118.0	165.0
D0500032	7.8	302	9.6	94.7	2.17	1.18	1.18	30	0.12	0.06	9.25	163.0	199.0
D0500041	7.9	283	11.5	100.0	4.33	n.d.	1.06	24	0.04	0.03	9.05	80.0	144.0
D0500042	8.0	299	9.7	95.9	1.83	1.15	1.24	24	0.11	0.04	9.12	179.0	302.0
D0500051	8.4	318	12.3	104.0	2.18	n.d.	1.30	24	0.03	0.02	13.42	100.0	158.0
D0500052	8.2	304	9.4	109.0	2.01	0.20	1.14	20	0.17	0.02	10.38	163.0	285.0
D0500061	8.7	213	13.2	110.0	1.87	n.d.	0.88	28	0.04	0.08	19.93	161.0	224.0
D0500062	7.9	196	9.4	92.5	1.45	0.42	0.78	30	0.14	0.04	20.69	151.0	245.0
D0500071	7.0	136	12.9	105.0	2.53	n.d.	0.52	19	2.26	0.03	16.17	40.0	90.0
D0500072	7.3	136	10.4	111.0	1.49	1.67	0.50	30	0.13	0.03	17.41	72.0	122.0
D0500081	8.6	427	11.4	97.2	2.57	1.61	2.04	32	0.13	0.05	21.46	231.0	306.0
D0500082	8.2	440	9.5	104.0	1.52	0.43	1.76	22	0.15	0.03	18.54	304.0	433.0
D0500091	8.2	327	11.7	99.5	4.14	n.d.	1.40	28	0.02	0.02	14.07	98.0	144.0
D0500092	8.1	372	9.7	95.0	1.79	1.25	1.46	42	0.09	0.02	9.92	170.0	268.0
D0500101	7.0	153	12.9	103.3	3.60	n.d.	0.74	20	0.03	0.01	6.74	49.0	99.0
D0500102	8.0	279	8.9	97.5	5.57	0.75	1.00	21	0.23	0.08	5.57	174.1	367.8
D0500111	6.7	225	12.1	95.2	3.12	n.d.	1.16	26	0.13	0.04	8.09	43.0	114.0
D0500112	7.8	263	10.8	103.9	5.21	0.59	1.02	30	0.46	0.14	11.51	115.7	243.4
D0500121	7.0	164	11.7	100.0	4.07	n.d.	0.86	20	0.64	0.05	6.95	300.0	412.0
D0500122	7.7	257	13.0	136.0	3.06	0.65	0.92	36	0.06	0.10	8.68	278.0	753.3
D0500131	6.7	125	11.9	99.0	2.47	n.d.	0.84	20	0.09	0.03	4.73	57.0	103.0
D0500132	7.8	194	13.2	139.0	3.51	0.55	0.92	28	0.07	0.05	5.23	252.4	397.0
D0500141	7.6	170	11.3	97.2	2.04	n.d.	0.88	20	0.16	0.06	6.38	186.0	231.0
D0500142	7.3	364	9.7	91.1	2.61	1.40	1.55	30	0.55	0.26	8.85	552.0	568.0
D0500151	7.1	144	12.4	102.0	4.26	0.32	0.52	20	0.06	0.02	6.41	88.0	99.0
D0500152	8.0	208	10.3	103.4	1.35	1.00	1.00	22	0.07	0.02	3.20	136.3	157.7

Site code	pH-value	Conductivity [µS/cm]	Dissolved oxygen content [mg/l]	Oxygen saturation [%]	BOD_5 [mg/l]	Alkalinity [mmol/l]	Total hardness [mmol/l]	Chloride [mg/l]	Ammonium [mg/l]	Nitrite [mg/l]	Nitrate [mg/l]	Ortho-phosphate [µg/l]	Total phosphate [µg/l]
D0500161	7.4	128	12.5	108.0	2.00	n.d.	0.80	18	0.02	0.01	6.34	50.0	88.0
D0500162	9.9	194	12.4	128.9	0.89	0.90	1.00	22	0.03	0.03	7.14	46.1	75.5
D0500171	7.2	211	12.5	101.0	4.11	0.56	0.84	22	0.16	0.07	11.62	177.0	188.0
D0500172	8.4	328	11.4	109.0	1.97	1.00	1.25	28	0.13	0.10	13.77	1041.5	896.0
D0500181	7.4	212	12.6	102.0	3.95	0.74	0.86	20	0.12	0.09	11.40	176.0	212.0
D0500182	8.5	319	10.5	101.7	1.57	1.60	1.50	28	0.03	0.03	8.37	609.5	651.1
D0500191	7.0	353	11.7	96.0	12.26	1.70	n.d.	42	0.92	0.18	16.73	113.0	172.8
D0500192	8.7	396	13.1	140.0	3.40	0.60	1.02	34	0.05	0.17	13.35	92.7	250.4
D0500201	7.0	210	12.8	102.4	6.59	0.30	n.d.	30	0.17	0.06	18.27	71.7	107.7
D0500202	8.0	204	13.1	144.0	1.71	1.47	0.70	20	0.11	0.05	19.63	161.0	239.0

Appendix 6. Taxa list of the spring samples of the mid-sized streams in lower mountainous areas of Germany (stream type 9) (Ind/m^2). (Bi = Bivalvia, Co = Coleoptera, Cr = Crustacea, Di = Diptera, Ep = Ephemeroptera, Ga = Gastropoda, He = Heteroptera, Hi = Hirudinea, Me = Megaloptera, Od = Odonata, Ol = Oligochaeta, Pl = Plecoptera, Tr = Trichoptera,Tu = Turbellaria)

Taxa group	Taxon	Author	D0500011	D0500021	D0500031	D0500041	D0500051	D0500061	D0500071	D0500081	D0500091	D0500101	D0500111	D0500121	D0500131	D0500141	D0500151	D0500161	D0500171	D0500181	D0500191	D0500201
Tu	Dugesia gonocephala	(DUGES, 1830)	0	0	0	0	0	0	0	18.4	0	0	0	0	0	0	0	0	0	0	0	0
Tu	Dugesia sp.		0	2.4	0	0	0	0	0	0	0.8	0	0	0	0	0	5.6	0	0	4.8	0	0
Tu	Turbellaria Gen. sp.		0	0.8	0	0	0	2.4	0	13.6	0	0	0	0	0	0	8	0	0.8	7.2	5.6	0
Ga	Ancylus fluviatilis	O.F. MÜLLER, 1774	8	7.2	4	17.6	8.8	9.6	52.8	10.4	48	4	0	8	1.6	1.6	40.8	23.2	62.4	23.2	65.6	4
Ga	Gyraulus albus	(O.F. MÜLLER, 1774)	0	0	0	0	0	1.6	0	0	0	0.8	0	0	0	0	0	0	0	0	1.6	0
Ga	Gyraulus sp.		0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ga	Physidae Gen. sp.		0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0
Ga	Potamopyrgus antipodarum	(GRAY, 1843)	0	0	0	0	0	0.8	0	0	0	2.4	0	0	0	0	0	0	0	0	0	0.8
Ga	Radix balthica	(LINNAEUS, 1758)	0	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0	8.8	0
Ga	Radix balthica/labiata		0	0	0.8	1.6	6.4	0	0	0	0	0	0	0	0.8	0	0	0	0	0.8	0	0
Ga	Radix labiata	(ROSSMÄSSLER, 1835)	0	0	0	0	0	0	0	0	0	8.8	0	0	0	0	0	0	0	0	0	0
Ga	Radix sp.		0	0	0	0	0	0	0	0.8	0	0.8	0	0.8	0.8	0	0	0	0	0	8.8	0

Taxa group	Taxon	Author	D0500011	D0500021	D0500031	D0500041	D0500051	D0500061	D0500071	D0500081	D0500091	D0500101	D0500111	D0500121	D0500131	D0500141	D0500151	D0500161	D0500171	D0500181	D0500191	D0500201
Bi	Pisidium casertanum	(POLI, 1791)	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0
Bi	Pisidium subtruncatum	MALM, 1855	0	0	0	0	0	0	0	2.4	0	0	0	0	0	0	0	0	0	0	0	0
Bi	Sphaerium corneum	(LINNAEUS, 1758)	0	0	0	0	0	6.4	0	0	4.8	0	0	0	0	0	0	0	0	0	0	0
Ol	Eiseniella tetraedra	(SAVIGNY, 1826)	0	1.9	0	2.7	0.8	0.8	2.4	8	0	0.8	0	0	0.8	0	4.2	1	0.8	0	0	0.8
Ol	Enchytraeidae Gen. sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Ol	Haplotaxidae Gen. sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0
Ol	Lumbricidae Gen. sp.		3.2	7.6	3.2	0	0	0.8	4.5	3.2	0.8	0.8	0	2.9	0	0	3.1	1	0	0	0	0
Ol	Lumbriculidae Gen. sp.		0	9.5	0	6.5	33.6	4.8	0	4	19.7	3.2	38.5	1.5	0	1.9	4.2	7	4	32	0	0
Ol	Lumbriculus variegatus	(MÜLLER, 1774)	0	0	0	0	0	0	0	0	0	0	0	0	0	1.9	2.1	0	0	6.4	0	0
Ol	Naididae Gen. sp.		0	0	4	2.7	0	0	0	2.4	0	1.6	0	0	0	0	4.2	0	0	0	0	0
Ol	Oligochaeta Gen. sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6
Ol	Stylodrilus heringianus	CLAPAREDE, 1862	0.8	0.9	0	17.4	0	0	0	1.6	4	0.8	4.3	14.5	0	33.8	7.3	3	0	5.6	0	0
Ol	Tubificidae Gen. sp.		4.8	1	4	0	0	0.8	34	5.6	2.7	0.8	2.8	6.4	0	0	2.1	0	0	0.8	0	0
Hi	Dina punctata	JOHANSSON, 1927	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0
Hi	Erpobdella nigricollis	(BRANDES, 1900)	0	0	0	0	0	0	2.4	0	0	0	0	0	0	0	0	0	0	0	1.6	0
Hi	Erpobdella octoculata	(LINNAEUS, 1758)	0	0.8	9.6	4	0	13.6	12	21.6	1.6	3.2	2.4	15.2	0	8.8	5.6	14.4	22.4	11.4	109.6	0.8
Hi	Erpobdella vilnensis	(LISKIEWICZ, 1925)	0	0	0	0	0	4	0.8	0	0	0	0	0	0	0	0	0	1.6	0	0	0
Hi	Erpobdellidae Gen. sp.		0	0	0.8	0	0	4.8	0	1.6	2.4	0	0	0	0	2.4	0	0.8	14.4	0	47.2	5.6
Hi	Glossiphonia complanata	(LINNAEUS, 1758)	0	0	0	0	0	3.2	0.8	2.4	1.6	0	0.8	0	0	0	0.8	0	0.8	0	0.8	0
Hi	Glossiphonia nebulosa	KALBE, 1964	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0.8	0	0.8	1.6
Hi	Glossiphoniidae Gen. sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6
Hi	Haemopis sanguisuga	(LINNAEUS, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0
Hi	Helobdella stagnalis	(LINNAEUS, 1758)	0	0	0	0	0	4.8	0	0	0	0	0.8	0	0	0	0	0.8	0.8	0	16	0
Hi	Piscicolidae Gen. sp.		0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0
Hi	Trocheta pseudodina	NESEMANN, 1990	0	0	5.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Cr	Asellus aquaticus	(LINNAEUS, 1758)	0	0	4.8	0	0	0	0	0	0	0	4.8	0	0	0	0	0	0	0	260	0
Cr	Gammarus fossarum	KOCH in PANZER, 1836	0	0	0	0	90.4	101.6	4.3	118.3	0	0	0	0	0	0	0	0	0	0	0	304.8
Cr	Gammarus fossarum/pulex		0	0	0	0	0	0	0	0	0	0.8	7.2	0	0	0	0	0	0	0	0	0
Cr	Gammarus pulex	(LINNAEUS, 1758)	0	0	8	4.8	0	0	19.5	25.7	4.8	0	0	0	0	0	3.2	0	0	0	64	38.4
Cr	Niphargus sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.6	0	0	0	0	0

Taxa group	Taxon	Author	D0500011	D0500021	D0500031	D0500041	D0500051	D0500061	D0500071	D0500081	D0500091	D0500101	D0500111	D0500121	D0500131	D0500141	D0500151	D0500161	D0500171	D0500181	D0500191	D0500201
Ep	Baetis alpinus	PICTET, 1843-1845	0	0	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ep	Baetis buceratus	EATON, 1870	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0
Ep	Baetis fuscatus	(LINNAEUS, 1761)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8
Ep	Baetis lutheri	MÜLLER-LIEBENAU, 1967	0	0	0	11.2	8.8	0	0	0.8	30.4	0	0	0.8	0	0	11.2	0	3.2	0	0	4
Ep	Baetis rhodani	PICTET, 1843-1845	60	66.4	29.6	87.2	57.6	5.6	28	72	68.8	31.2	0	14.4	1.6	91.2	76	16.8	97.6	68	7.2	28.8
Ep	Baetis scambus	EATON, 1870	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8
Ep	Baetis sp.		40	87.2	4.8	87.2	156	1.6	20	26.4	92	4	4.2	6.4	0	35.2	39.2	5.6	40	31.2	0.8	25.6
Ep	Baetis vernus	CURTIS, 1834	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0.8	0	0.8	0	0	0
Ep	Caenis luctuosa	(BURMEISTER, 1839)	0	0	0	0	0	5.6	0	0	0	0.8	0	0.8	0	0	68.5	4.8	4.8	0	0	4
Ep	Caenis rivulorum	EATON, 1884	2.4	0.8	0	0	0	0	0	0	0	0	0	0	0	0	1.9	24	0.8	0	0	0
Ep	Centroptilum luteolum	(MÜLLER, 1776)	0.8	0	0	0	0	0	0	0	0	0	13.2	0	0	0	0	0	0	0	0	0
Ep	Ecdyonurus dispar	(CURTIS, 1834)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11.2
Ep	Ecdyonurus insignis	(EATON, 1870)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0
Ep	Ecdyonurus macani	THOMAS & SOWA, 1970	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	1.6	0.8	5.6	0	0
Ep	Ecdyonurus torrentis	KIMMINS, 1942	0	0	0	0	4	3.2	2.4	7.2	1.6	0	0	0	0	1.6	0	0.8	0	0	0	2.4
Ep	Ecdyonurus venosus	(FABRICIUS, 1775)	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ep	Ecdyonurus venosus-Gr.		9.6	12.8	1.6	0.8	4.8	0	2.4	8	0.8	0	0	0.8	0.8	2.4	0	3.2	0	0.8	0	20
Ep	Epeorus sylvicola	(PICTET, 1865)	23.2	87.2	0	6.4	1.6	0	4	0	0	0	0	1.6	0	2.4	12	0	17.6	3.2	0	0.8
Ep	Ephemera danica	MÜLLER, 1764	0	0	0	0.8	1.6	11.2	5.6	12.8	3.2	0.8	0	0	1.6	0	0	0	0	4	0	4.8
Ep	Ephemerella mucronata	(BENGTSSON, 1909)	0	0	0	0	0	0	0	0	0	1.6	0	0	0	48	0	0	0	0	0	0
Ep	Habroleptoides confusa	SARTORI & JACOB, 1986	0.8	5.6	0.8	2.4	0	8	0	0	11.2	0.8	0	4	16.8	0.8	4	0.8	26.4	4.8	0	20.2
Ep	Habrophlebia sp.		0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ep	Heptagenia sp.		0	0	0	0	7.2	2.4	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0
Ep	Heptagenia sulphurea	(MÜLLER, 1776)	0	0	0	0	2.4	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ep	Heptageniidae Gen. sp.		9.6	6.4	0.8	1.6	1.6	0	0	0	0	0	0	0.8	1.6	0	9.6	0	4.8	12	0.8	0.8
Ep	Leptophlebiidae Gen. sp.		0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ep	Paraleptophlebia submarginata	(STEPHENS, 1835)	0	0	1.6	0	0	11.2	0	0.8	0	0	0	0	0	0	4.8	0.8	0	0	0	18.2
Ep	Rhithrogena hercynia	LANDA, 1969	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8.8	0	0.8	0	0	0
Ep	Rhithrogena semicolorata-Gr.		135.2	130.4	0	8	0	0.8	0	0.8	10.4	0	0	5.6	25.6	4	188	4	31.2	64.8	0	2.4
Ep	Serratella ignita	(PODA, 1761)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40

Taxa group	Taxon	Author	D0500011	D0500021	D0500031	D0500041	D0500051	D0500061	D0500071	D0500081	D0500091	D0500101	D0500111	D0500121	D0500131	D0500141	D0500151	D0500161	D0500171	D0500181	D0500191	D0500201
Ep	Torleya major	KLAPÁLEK, 1905	0	0	166.4	150.4	121.6	35.2	30.4	94.4	31.2	0.8	0	3.2	5.6	0	6.4	12	31.2	65.6	0	11.2
Od	Onychogomphus forcipatus	(LINNAEUS, 1758)	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Od	Ophiogomphus cecilia	(FOURCROY, 1785)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0
Pl	Amphinemura sp.		4	22.4	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0
Pl	Brachyptera risi	(MORTON, 1896)	0	2.4	0	2.4	7	0	1.6	0	0	0	0	0	0	0	0	0	0	4	0	0
Pl	Brachyptera seticornis	(KLAPALEK, 1902)	0	1.6	0	0	1.8	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0
Pl	Isoperla sp.		0.8	1.6	0.8	0	0	0	0	0	0	0	0	6.4	10.4	0	76	12	4.8	16.8	0	0
Pl	Leuctra nigra	(OLIVIER, 1811)	0	0.8	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pl	Leuctra sp.		0.8	13.6	0	0	0	0	0	0	0.8	3.2	0	0	0	0	0	0	0	0.8	1.6	0
Pl	Nemoura avicularis	MORTON, 1894	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0
Pl	Nemoura cinerea	(RETZIUS, 1783)	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	3.2	0	0	0
Pl	Nemoura sciurus	AUBERT, 1949	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0
Pl	Nemoura sp.		0	2.4	3.2	0	0	0	0	0	0	0.8	0	0.8	0	2.4	0	0	3.2	0	0.8	0.8
Pl	Perla burmeisteriana	CLAASSEN, 1936	0	0	0	0	0	0	0.8	0	3.2	0	0	0	0	0	1.6	0.8	0	8	0	0
Pl	Perla marginata	(PANZER, 1799)	0	0.8	0	0	0	0	0.8	0	0.8	0	0	0	0	0	0	0	0	0	0	0
Pl	Perlodes microcephalus	(PICTET, 1833)	0	0.8	0	0	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pl	Protonemura meyeri	(PICTET, 1841)	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pl	Protonemura sp.		0	7.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pl	Siphonoperla sp.		5.6	10.4	0	0	0	0	0	0	0	0	0	1.6	11.2	0.8	6.4	52	2.4	15.2	0	0
He	Sigara striata	(LINNAEUS, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.2	0
Me	Sialis fuliginosa	PICTET, 1836	0	0	0	0	0	0	3.2	0	0	0	0	0	0	0	0	0.8	0	0	2.4	0
Me	Sialis lutaria	(LINNAEUS, 1758)	0	0	0	0	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	2.4	0
Co	Brychius elevatus Ad.	(PANZER, 1794)	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Co	Brychius elevatus Lv.	(PANZER, 1794)	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Co	Dryops sp. Lv.		0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0
Co	Elmis aenea Ad.	(MÜLLER, 1806)	0	0	0	0	10	0	0	3.9	1.3	0	0	0	0	0	0	0	2.6	0	0	0
Co	Elmis aenea/maugetii Ad.		0	0	4.8	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2	0	0	0
Co	Elmis maugetii Ad.	LATREILLE, 1798	0	0	0	4.8	74	7.2	0	28.9	27.5	0	0	0	0	0.8	15.2	0.8	9	10.4	0	0
Co	Elmis rioloides Ad.	KUWERT, 1890	0	2.4	0	0	18.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Co	Elmis sp. Ad.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8

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Co	Elmis sp. Lv.		1.6	3.2	29.6	8	28	14.4	4.8	26.4	23.2	2.4	0	0	0	0	19.2	3.2	9.6	8.8	0	10.4
Co	Esolus angustatus Ad.	(MÜLLER, 1821)	0	0	0	0	0	0	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0
Co	Esolus parallelepipedus Ad.	(MÜLLER, 1806)	0	0	0	0	0	0	0	0	10.4	0	0	0	0	0	12.8	0	0	0.8	0	0
Co	Esolus sp. Lv.		0	0	0	0	0	0	0	0	6.4	0	0	0	0.8	0	5.6	0	0	1.6	0	0
Co	Haliplus sp. Lv.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.4	0
Co	Helophorus arvernicus Ad.	MULSANT, 1846	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Co	Hydraena dentipes Ad.	GERMAR, 1844	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	3.2	0	0	0	0	0
Co	Hydraena gracilis Ad.	GERMAR, 1824	0	2.4	2.4	0.8	0	0	0	0	2.4	0	0	0	0	5.6	3.2	1.6	4	0.8	0	0
Co	Hydraena reyi Ad.	KUWERT, 1888	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0
Co	Hydraena sp. Lv.		0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0
Co	Limnius opacus Ad.	MÜLLER, 1806	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	1.6	0	0	0.8	0	0
Co	Limnius opacus Lv.	MÜLLER, 1806	0	0	0	0	0	0	0	0	4.8	0	0	0	0	0	19.2	0	0	0.8	0	0
Co	Limnius perrisi Lv.	(DUFOUR, 1843)	0	0.8	0	1.6	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0
Co	Limnius volckmari Ad.	(PANZER, 1793)	0	0	0	0	2.4	0	0	5.6	8.8	0	0	0	0	0	0	0	1.6	1.6	0	0
Co	Limnius volckmari Lv.	(PANZER, 1793)	0	0	0.8	4	6.4	2.4	0	5.6	4	0	0	0	0	0	6.4	0	2.4	1.6	0	0
Co	Nebrioporus elegans Ad.	(PANZER, 1794)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6	0
Co	Nebrioporus sp. Lv.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0
Co	Orectochilus villosus Ad.	(MÜLLER, 1776)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6	0	0
Co	Orectochilus villosus Lv.	(MÜLLER, 1776)	0	0	1.6	8.8	10.4	14.4	0	1.6	28.8	0	0	0	0	0	5.6	1.6	2.4	1.6	0	6.4
Co	Oreodytes sanmarkii Ad.	(SAHLBERG, 1834)	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0
Co	Oulimnius tuberculatus Ad.	(MÜLLER, 1806)	0	0	4.8	0	20.8	3.2	0	4	2.4	0	0	0	0	0	8	0	8.8	4	0	0
Co	Oulimnius tuberculatus Lv.	(MÜLLER, 1806)	0	0.8	0	0.8	0	2.4	2.4	0.8	0.8	0	0	0	0	0.8	4	0	0.8	0	0	0
Co	Platambus maculatus Lv.	(LINNAEUS, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0
Co	Stenelmis canaliculata Lv.	(GYLLENHÅL, 1808)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.2	0	0	0	0	0
Tc	Agapetus fuscipes	CURTIS, 1834	0	0	0	0	11.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Agapetus ochripes	CURTIS, 1834	0	0	0	116.8	14.9	0	0	0	4.8	0	0	0	0	0	0	0	0	0	0	7.2
Tc	Allogamus auricollis	(PICTET, 1834)	0	0	2.4	1.6	0	12.8	4	24.8	0	0	0	0	0	4.8	0	1.6	23.2	17.6	8	45.6
Tc	Anabolia nervosa	(CURTIS, 1834)	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0.8	0	1.6	0	0	0
Tc	Anomalopterygella chauviniana	(STEIN, 1874)	0	13.6	0	0	0	0	0	0	0	0	0	0	1.6	0	0	0	0.8	3.2	0	0
Tc	Athripsodes albifrons	(LINNAEUS, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0

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Tc	Athripsodes bilineatus	(LINNAEUS, 1758)	0	0.8	0	0	0	0	0	0	0	4.8	0	0	1.6	0	0	0	0.8	1.6	0	0
Tc	Athripsodes cinereus	(CURTIS, 1834)	0	0	0	1.6	0	20	1.6	0	4	0	0	0	0	0	11.6	0.8	0.8	0	0	1.6
Tc	Athripsodes sp.		0	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Brachycentrus maculatus	(FOURCROY, 1785)	0	0	45.6	155.2	38.4	73.6	16	98.4	98.4	0	0	0	0	0	0	0	0	0	0	144.8
Tc	Brachycentrus sp.		0	0	0	0	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Ceraclea annulicornis	(STEPHENS, 1836)	0	0	0	0.8	0	59.2	0.8	0	5.6	0	0	0	0	0	3.2	0.8	0	0.8	0	31.2
Tc	Ceraclea nigronervosa	(RETZIUS, 1783)	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0
Tc	Chaetopteryx villosa	(FABRICIUS, 1789)	0	0	0	0	0	0	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Cheumatopsyche lepida	(PICTET, 1834)	0	0	0	21.6	3.2	8.8	0	0	404.8	0	0	0	0	0	60	0.8	6.4	12.8	0	12
Tc	Chimarra marginata	(LINNAEUS, 1767)	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0
Tc	Crunoecia irrorata	(CURTIS, 1834)	0	0	0	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0
Tc	Cyrnus trimaculatus	(CURTIS, 1834)	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Ecclisopteryx dalecarlica	KOLENATI, 1848	0.8	3.2	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0
Tc	Goera pilosa	(FABRICIUS, 1775)	0	0	0	0	0	0	0	0	0	1.6	0	0	0	0	0.8	0	0	1.6	0.8	5.6
Tc	Halesus digitatus	(SCHRANK, 1781)	0	0	0	0	0	0.8	3.2	0	0	0.8	0	0	0	3.2	0	0	0	0	0	4.8
Tc	Halesus radiatus	(CURTIS, 1834)	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0
Tc	Halesus sp.		0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Halesus tesselatus	(RAMBUR, 1842)	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Hydropsyche dinarica	MARINKOVIC, 1979	0	22.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Hydropsyche incognita	PITSCH, 1993	7.2	9.6	3.2	45.6	73.6	1.6	4.8	0	73.6	1.6	0	1.6	0.8	4.8	0	11.2	12.8	7.2	1.6	26.4
Tc	Hydropsyche instabilis	(CURTIS, 1834)	0	0	0	0	0	0	1.6	0.8	0	0	0	0	0	0	0.8	0	0	0	0	0
Tc	Hydropsyche pellucidula	(CURTIS, 1834)	0	0	0	0	0.8	0	0.8	2.4	0	0.8	0	0	0	9.6	0	0	0	0	0	0
Tc	Hydropsyche siltalai	DÖHLER, 1963	0.8	4.8	8.8	53.6	164.8	17.6	20	66.4	93.6	28.8	0	19.2	2.4	64.8	55.2	16.8	55.2	29.6	6.4	12.8
Tc	Hydropsyche sp.		8	34.4	3.2	19.2	32.8	1.6	4.8	32	44	11.2	0	3.2	4.8	22.4	25.6	13.6	28.8	26.4	1.6	9.6
Tc	Hydroptila sp.		0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Lasiocephala basalis	(KOLENATI, 1848)	1.6	0	0	5.6	0.8	45.6	5.6	18.4	0	0	0	0	0	0	0	0	0.8	0	0	160.8
Tc	Lepidostoma hirtum	(FABRICIUS, 1775)	13.6	60	8	11.2	0	100	36	0.8	0	10.4	0	0	0	0	32	7.2	4	7.2	1.6	26.4
Tc	Leptoceridae Gen. sp.		0	0	0.8	0.8	0	0	0	0	0.8	0.8	0	0	0	0	1.6	1.6	0	0	0	0
Tc	Limnephilidae Gen. sp.		0	0.8	0	3.2	0	0	1.6	12	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Limnephilus flavicornis	(FABRICIUS, 1787)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0

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Tc	Lithax obscurus	(HAGEN, 1859)	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0
Tc	Micrasema longulum	McLACHLAN, 1876	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Micrasema minimum	McLACHLAN, 1876	49.6	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Micrasema setiferum	(PICTET, 1834)	0	0	0	0	36.8	203.2	0	0	0	0	0	0	0	0	255.2	5.6	0	6.4	0	76.8
Tc	Mystacides azurea	(LINNAEUS, 1761)	0	0	0	0	0	0	0	0	0	6.4	0	0	0	0	0	0	0	0	0	0
Tc	Mystacides nigra	(LINNAEUS, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0
Tc	Mystacides sp.		0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0
Tc	Odontocerum albicorne	(SCOPOLI, 1763)	0	0	0	0	8	0	0	9.6	0	0	0	0	0	0	0	0	0	0.8	0	0
Tc	Oecetis testacea	(CURTIS, 1834)	0	2.4	0	0	0	2.4	0.8	0	0	0.8	0	0	0	0	0	0.8	0	0	0	0
Tc	Plectrocnemia conspersa	(CURTIS, 1834)	0	0	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0	0.8
Tc	Plectrocnemia geniculata	McLACHLAN, 1871	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Plectrocnemia sp.		0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Polycentropus flavomaculatus	(PICTET, 1834)	0	0	4.8	2.4	3.2	8.8	0	0	4.8	0	0	0.8	0	0	5.6	5.6	8.8	5.6	2.4	2.4
Tc	Polycentropus sp.		0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Potamophylax latipennis	(CURTIS, 1834)	0	0	0	0	0	0	0	0	0	0	0	0	0	4.8	0	0	0	0	0	0
Tc	Potamophylax luctuosus	(PILLER & MITTERPACHER, 1783)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	2.4	0	0	0
Tc	Potamophylax rotundipennis	(BRAUER, 1857)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6	0
Tc	Potamophylax sp.		0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Psychomyia pusilla	(FABRICIUS, 1781)	0	0	0	0.8	0	0.8	2.4	0	0	9.6	0	0	0	0	1.6	0	0	0	0	0
Tc	Rhyacophila dorsalis	(CURTIS, 1834)	0	1.6	4.8	18.5	10.4	0	0	14.4	13.6	0	0	0	0	0	0	0	0	0	0	2.4
Tc	Rhyacophila fasciata	HAGEN, 1859	0	1.6	1.6	7.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Rhyacophila nubila	(ZETTERSTEDT, 1840)	0	0	0	0	0	0	0	0	0	11.2	0	29.6	0	21.6	37.6	3.2	47.2	16.8	0	0
Tc	Rhyacophila sp.		0.8	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0
Tc	Sericostoma sp.		5.6	17.6	0.8	34.4	8	32	17.6	50.4	8	0	0	0	1.6	16	0	1.6	12	9.6	0	84.8
Tc	Silo nigricornis	(PICTET, 1834)	0	0	0	0	0	7.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Silo pallipes	(FABRICIUS, 1781)	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Silo piceus	(BRAUER, 1857)	23.2	10.4	0	8.8	3.2	0	0.8	0.8	27.2	0	0	0	0	5.6	0.8	0	4.8	7.2	0	2.4
Tc	Silo sp.		0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0
Tc	Tinodes waeneri	(LINNAEUS, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.2	0
Di	Atherix sp.		7.2	0	0.8	0	0.8	1.6	0	1.6	0	2.4	0	0	4.8	0.8	0.8	0.8	0	0	2.4	2.4

Taxa group	Taxon	Author	D0500011	D0500021	D0500031	D0500041	D0500051	D0500061	D0500071	D0500081	D0500091	D0500101	D0500111	D0500121	D0500131	D0500141	D0500151	D0500161	D0500171	D0500181	D0500191	D0500201
Di	Bazarella sp.		0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0
Di	Berdeniella sp.		0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0
Di	Ceratopogonidae Gen. sp.		1.6	0.8	8	2.4	0	0	0.8	0	4	0.8	0	4	0	0.8	2.4	6.4	4.8	0	0.8	0
Di	Chironomidae Gen. sp.		0	0	0	1.6	2.4	0.8	4.8	17.6	0.8	0	6.4	0	0.8	0	0	0.8	5.6	0.8	76.8	2.4
Di	Chironomini Gen. sp.		1.6	0	0	4.8	20	344.6	204	28.8	4.8	3.2	20.8	1.6	4	0	6.6	6.4	0.8	1.6	1215	24
Di	Diamesinae Gen. sp.		8.8	0.8	0	0	4.8	6.4	12.8	0	12	1.6	0	26.4	0	0	0	0	0.8	0	60.8	0
Di	Dicranota sp.		0	0.8	0	0.8	0	0	4	0.8	0	0	0	1.6	1.6	3.2	0	4	2.4	8	0.8	0
Di	Eloeophila sp.		0	0	0.8	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0.8	0	0	0
Di	Empididae Gen. sp.		0	1.6	1.6	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0.8	0	0
Di	Idioptera sp.		10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Di	Limoniidae Gen. sp.		0	0	0	0	0	0.8	0	12.8	0	0	0	0	0	0	0	0	0.8	0	0	0
Di	Liponeura sp.		2.4	39.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Di	Muscidae Gen. sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0
Di	Orthocladiinae Gen. sp.		3.2	10.4	0	97.6	71.2	34.4	200	260	0.8	23.2	11.2	0	3.2	19.2	24.8	18.4	49.6	21.6	320.8	6.4
Di	Paradelphomyia sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0
Di	Pedicia sp.		0	0.8	0.8	0.8	0.8	0.8	3.2	0	4	19.2	0	0	0	0	0	0.8	0	0	0	0
Di	Pericoma sp.		0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Di	Prodiamesinae Gen. sp.		0	0	0	1.6	0	16	9.6	62.4	0	3.2	283.2	0	0	4	0	0	0	0	0	0
Di	Prosimulium hirtipes	(FRIES, 1824)	0	25.6	0	0	14.4	127.2	35.2	0	0.8	0	0	0.8	0	42.4	476	2.4	53.6	521.6	0	0
Di	Prosimulium sp.		18.4	2.4	1.6	0	0	579.2	0.8	0	460.8	30.4	0	141.6	1.6	563.2	14.4	2.4	1008	4.8	0	502.4
Di	Prosimulium tomosvaryi	(ENDERLEIN, 1921)	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	25.6	0	0	0	0	0
Di	Rhabdomastix sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0
Di	Rhagionidae Gen. sp.		1.6	20	27.2	0.8	0	2.4	12	8.8	0	4.8	0	8	10.4	0.8	0	31.2	0	0	0	0
Di	Simuliidae Gen. sp.		0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0.8	0	0	0	0	0.8
Di	Simulium argyreatum	MEIGEN, 1838	0	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Di	Simulium equinum	(LINNAEUS, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25.6	0	0	0	0	0
Di	Simulium erythrocephalum	(DE GEER, 1776)	2.4	1.6	0	0	0	0	0	12.8	0	2.4	0	25.6	0	0	0	0	0	0	0	0
Di	Simulium lineatum	(MEIGEN, 1804)	0	0	0	0	3.2	0	0	0	0	0	0	0	0	0	52	0	0	0	0	0
Di	Simulium naturale	DAVIES, 1966	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0
Di	Simulium ornatum-Gr.		0	0	0.8	0	4.8	0	0	0	0	0	0	0	0	0	0	0	0	3.2	0	0

Taxa group	Taxon	Author	D0500011	D0500021	D0500031	D0500041	D0500051	D0500061	D0500071	D0500081	D0500091	D0500101	D0500111	D0500121	D0500131	D0500141	D0500151	D0500161	D0500171	D0500181	D0500191	D0500201
Di	Simulium paramorsitans	RUBZOV, 1956	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12.8	0	0.8	0	0	0
Di	Simulium reptans	(LINNAEUS, 1758)	0	0	0	0	82.4	0	0	0	0	0	0	0	0	0	153.6	0	0	0	0	0
Di	Simulium rostratum	(LUNDSTRÖM, 1911)	5.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.2	0	0	0	0
Di	Simulium sp.		34.4	84.8	13.6	0	4.8	0	2.4	3.2	25.6	17.6	0	0	0	0	115.2	4	6.4	3.2	0	0
Di	Simulium variegatum	MEIGEN, 1818	0	0	0	0	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Di	Stratiomyiidae Gen. sp.		0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0
Di	Tabanidae Gen. sp.		0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Di	Tanypodinae Gen. sp.		1.6	0	0	0	0.8	8	16	16	2.4	0	128	0.8	0	4	0	3.2	0.8	0.8	3.2	30.4
Di	Tanytarsini Gen. sp.		0.8	13.6	0	3.2	0.8	5	18.4	22.4	2.4	0	80	0.8	0	8	1	4	16	2.4	30	1.6
Di	Tipula maxima-Gr.		0	1.6	1.6	0	0	0.8	0	0	0	0	0.8	0.8	0	1.6	0	0	0	0	0	0
Di	Tipula sp.		0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0
Di	Tonnoiriella sp.		0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 7. Taxa list of the summer samples of the mid-sized streams in lower mountainous areas of Germany (stream type 9) (Ind/m^2). (Bi = Bivalvia, Co = Coleoptera, Cr = Crustacea, Di = Diptera, Ep = Ephemeroptera, Ga = Gastropoda, He = Heteroptera, Hi = Hirudinea, Me = Megaloptera, Od = Odonata, Ol = Oligochaeta, Pl = Plecoptera, Tr = Trichoptera,Tu = Turbellaria)

Taxa group	Taxon	Author	D0500012	D0500022	D0500032	D0500042	D0500052	D0500062	D0500072	D0500082	D0500092	D0500102	D0500112	D0500122	D0500132	D0500142	D0500152	D0500162	D0500172	D0500182	D0500192	D0500202
Tu	Dendrocoelum sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0
Tu	Dugesia gonocephala	(DUGES, 1830)	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tu	Dugesia sp.		0.8	0	0	0	0	0	0	0.8	0	0	0	0	0	6.4	0	0	0	1.6	0	0
Tu	Turbellaria Gen. sp.		0	0.8	0	0	2.4	0	0	4.8	0	0	0	9.6	0	6.4	0	0	0	7.2	0	0
Ga	Ancylus fluviatilis	O.F. MÜLLER, 1774	14.4	87.2	12	7.2	276.8	12.8	132	20	45.6	35.2	0	322.4	17.6	8.8	76.8	32.8	121.6	22.4	6.4	183.2
Ga	Gyraulus albus	(O.F. MÜLLER, 1774)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0
Ga	Potamopyrgus antipodarum	(GRAY, 1843)	0	0	0	0	0.8	0	0	0	0	10.4	0	0	0	0	0	0	0	0	0	1.6
Ga	Radix auricularia	(LINNAEUS, 1758)	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ga	Radix balthica	(LINNAEUS, 1758)	0	0	0	0	2.4	0.8	0	0.8	0	1.6	0	0	0	0	0	0	0	0	0	0

Taxa group	Taxon	Author	D0500012	D0500022	D0500032	D0500042	D0500052	D0500062	D0500072	D0500082	D0500092	D0500102	D0500112	D0500122	D0500132	D0500142	D0500152	D0500162	D0500172	D0500182	D0500192	D0500202
Ga	Radix labiata	(ROSSMÄSSLER, 1835)	0	0	0	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0
Ga	Radix sp.		0	0	1.6	0	27.2	0.8	0	1.6	0	0.8	0	0.8	5.6	0	0	0	0.8	0	2.4	0
Bi	Pisidium casertanum	(POLI, 1791)	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0
Bi	Pisidium sp.		0	1.6	0	0	0.8	0.8	0	1.6	0	0	0	0	0	0	0	0	0	0	0	0
Bi	Pisidium subtruncatum	MALM, 1855	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0.8	0	0	0	0	0
Bi	Sphaerium corneum	(LINNAEUS, 1758)	0	0	0	1.6	0	3.2	0	0	1.6	0	0	0	0	0	3.2	0	0	0	0	13.6
Ol	Eiseniella tetraedra	(SAVIGNY, 1826)	0	0	0.8	0.8	0	0	1.1	2.4	0	4	0.8	0	0	0	0	0	1.6	0.8	0	0
Ol	Lumbricidae Gen. sp.		0	0	0	0	0	0	18.3	1.6	0	0	0	0	0	0	0.8	4.8	0	4	0	0
Ol	Lumbriculidae Gen. sp.		1.6	3.2	1.6	8.9	0.8	18.9	34.3	30.4	30.8	0	2.4	2.3	2.4	42.4	2.4	0	28	12.8	1.6	9.6
Ol	Lumbriculus variegatus	(MÜLLER, 1774)	0	0	0	0	0	0	0	0	0	0	0	12.6	0	0	0	0	0	0	0	0
Ol	Naididae Gen. sp.		0	0	0	0	0	0	0	3.2	2.9	0	25.6	0	1.6	0.8	0	0	0.8	0	0	0
Ol	Oligochaeta Gen. sp.		0	0	0	0	0	0	0	0	0	3.2	0	0	0	0	0	0	0	0	0	0
Ol	Stylodrilus heringianus	CLAPAREDE, 1862	1.6	4	0	31.9	0	1	6.9	0.8	1.5	2.4	0	9.1	0	8	0	0	4	0	0	0.8
Ol	Tubificidae Gen. sp.		0	0	0	0	0	11.8	9.1	11.2	0	0	0	0	1.6	0	0	0	0.8	5.6	0	2.4
Hi	Dina lineata	(O.F. MÜLLER, 1774)	0	0	4.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hi	Erpobdella octoculata	(LINNAEUS, 1758)	0.8	8	8	2.4	0	19.2	7.2	8	0	2.4	2.4	14.4	4.8	30.4	12.8	1.6	22.4	9.6	24.8	3.2
Hi	Erpobdella testacea	(SAVIGNY, 1822)	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hi	Erpobdella vilnensis	(LISKIEWICZ, 1925)	0	0	0	0	0	4	8	0	0	0	0	0	4	0	0	0.8	1.6	0	0	0
Hi	Erpobdellidae Gen. sp.		0	0	1.6	0.8	0	0	7.2	0	2.4	2.4	0	0.8	0	8	2.4	0	15.2	2.4	17.6	1.6
Hi	Glossiphonia complanata	(LINNAEUS, 1758)	0	0	0	0	1.6	8	2.4	0.8	0	0	0	0	0	3.2	1.6	0	0.8	0	1.6	4
Hi	Glossiphonia nebulosa	KALBE, 1964	0	0	0.8	0	0	4	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0
Hi	Glossiphonia paludosa	(CARENA, 1824)	0	0	0	0	0	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8
Hi	Glossiphoniidae Gen. sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0.8	0	0.8	0	0
Hi	Helobdella stagnalis	(LINNAEUS, 1758)	0	0	1.6	0	0	17.6	0.8	0	0	0	4.8	0	0	0	4.8	0	7.2	0	9.6	7.2
Hi	Hemiclepsis marginata	(O.F. MÜLLER, 1774)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0
Hi	Piscicolidae Gen. sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17.6	0	0	0
Hi	Trocheta pseudodina	NESEMANN, 1990	0	0	4.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Cr	Asellus aquaticus	(LINNAEUS, 1758)	0	0	12	0	0	0	0	0	0	0	4.8	0	0	0	0	0	0	0	400	0
Cr	Gammarus fossarum	KOCH in PANZER, 1836	0	0	0	0	16.4	94.4	24.1	151.2	1.8	0	0	0	0	0	0	0	4.6	1.2	21.8	0
Cr	Gammarus fossarum/pulex		0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0

Taxa group	Taxon	Author	D0500012	D0500022	D0500032	D0500042	D0500052	D0500062	D0500072	D0500082	D0500092	D0500102	D0500112	D0500122	D0500132	D0500142	D0500152	D0500162	D0500172	D0500182	D0500192	D0500202
Cr	Gammarus pulex	(LINNAEUS, 1758)	0	0	23.2	32.8	197.2	0	173.5	0	11	0	38.4	0	0	10.4	67.2	0	3.4	1.2	51.8	0
Ep	Baetis buceratus	EATON, 1870	0	0	0	0	2.4	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0
Ep	Baetis fuscatus	(LINNAEUS, 1761)	6.4	1.6	0	17.1	0	2.4	0	0	12	0	0	4	0	0	6.4	0	0	1.6	0.8	0
Ep	Baetis fuscatus/scambus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
Ep	Baetis lutheri	MÜLLER-LIEBENAU, 1967	0	0	0	64	4.8	0	1.6	8	16	0	0	1.6	0	0	12	8.8	8.8	13.6	0	0
Ep	Baetis rhodani	PICTET, 1843-1845	12	5.6	5.6	21.6	0.8	3.2	16.8	27.2	0.8	66.4	0	11.2	0	78.4	96.8	6.4	78.4	35.2	0	0
Ep	Baetis scambus	EATON, 1870	0	0.8	19.2	14.9	16	0	6.4	5.6	5.6	40	0	7.2	0.8	0.8	0	0	25.6	8.8	0.8	0
Ep	Baetis sp.		106.4	24	247.2	392.8	88.8	4	32	160	79.2	108.8	0	16.8	0.8	308	59.2	21.6	325.6	149.6	0.8	0
Ep	Baetis vernus	CURTIS, 1834	0.8	0.8	3.2	0	4	0	0	1.6	0	0	0	0	0	0	0	0	0	0	0	0
Ep	Caenis beskidensis	SOWA, 1973	0	0	0	1.6	0	0	6.4	0	0	0	0	0	0	1.6	0	0	0	0	0	0
Ep	Caenis luctuosa	(BURMEISTER, 1839)	0	0	1.6	0	0.8	12.8	0	0.8	0	0	0	22.4	0	0	54.4	4	7.5	3.2	0	0
Ep	Caenis macrura	STEPHENS, 1835	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	3.7	5.6	1.6	0
Ep	Caenis pseudorivulorum	KEFFERMÜLLER, 1960	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0.8	0	0
Ep	Caenis rivulorum	EATON, 1884	0.8	3.2	0.8	0	0	0.8	0	0	0	0	0	0	0	3.2	0	0.8	0	0	0	0
Ep	Caenis sp.		0	0	0	0	0	0	0	0	0	0	0	0	4.8	0	0	0	0	0.8	0	0.8
Ep	Centroptilum luteolum	(MÜLLER, 1776)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0
Ep	Cloeon dipterum	(LINNAEUS, 1761)	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0
Ep	Cloeon sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0
Ep	Ecdyonurus dispar	(CURTIS, 1834)	0	0	11.2	11.2	6.4	4	3.2	0.8	6.4	0	0	0	0.8	2.4	12.8	0.8	0	3.2	5.6	0
Ep	Ecdyonurus torrentis	KIMMINS, 1942	5.6	1.6	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ep	Ecdyonurus venosus	(FABRICIUS, 1775)	0	0	0	0	0	0	0	0	0	0	0	12.8	0	0	0	0	0	0	0	0
Ep	Ecdyonurus venosus-Gr.		38.4	11.2	26.4	12.8	3.2	29.6	5.6	0	32.8	0	0	24	6.4	59.2	46.4	10.4	11.2	3.2	3.2	0.8
Ep	Electrogena sp.		0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ep	Epeorus sylvicola	(PICTET, 1865)	2.4	35.2	0	0	0	0	0	0	0	0	0	0.8	0	2.4	1.6	0	1.6	1.6	0	0
Ep	Ephemera danica	MÜLLER, 1764	1.6	3.2	0	2.4	0	10.4	2.4	12.8	3.2	0	0	0	0.8	0	0	0	1.6	3.2	0	0
Ep	Ephemera sp.		0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0
Ep	Habroleptoides confusa	SARTORI & JACOB, 1986	6.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.2	0	0	0
Ep	Habrophlebia lauta	EATON, 1884	8.2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Ep	Habrophlebia sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0
Ep	Heptagenia sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0

Taxa group	Taxon	Author	D0500012	D0500022	D0500032	D0500042	D0500052	D0500062	D0500072	D0500082	D0500092	D0500102	D0500112	D0500122	D0500132	D0500142	D0500152	D0500162	D0500172	D0500182	D0500192	D0500202
Ep	Heptageniidae Gen. sp.		2.4	1.6	2.4	0	0	0	0	0	0	0	0	0	0	0	0	1.6	0.8	2.4	0	0
Ep	Leptophlebiidae Gen. sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0
Ep	Procloeon pennulatum	(EATON, 1870)	0	0	0	0	0.8	0	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0
Ep	Rhithrogena semicolorata-Gr.		0.8	0.8	0	0	0	0	0	0	0	0	0	0	0	1.6	0	0	0	0	0	0
Ep	Serratella ignita	(PODA, 1761)	140.8	78.4	485.6	608.8	313.6	84	17.6	36.8	76.8	51.2	0	115.2	20	332.8	465.6	65.6	103.2	49.6	9.6	0
Od	Calopteryx splendens	(HARRIS, 1782)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0
Od	Onychogomphus forcipatus	(LINNAEUS, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0.8	0	0	0	0
Pl	Brachyptera risi	(MORTON, 1896)	0	11.3	64	0	0	0.8	0	2.4	4	0	0	0	9.6	4	0	5.6	0	0	0	0
Pl	Brachyptera seticornis	(KLAPALEK, 1902)	0	7.8	0.8	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0
Pl	Dinocras cephalotes	(CURTIS, 1827)	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pl	Isoperla sp.		0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pl	Leuctra geniculata	(STEPHENS, 1836)	17.6	6.4	197.6	40.8	8	20	4	19.2	31.2	0	0	25.6	0	11.2	44	15.2	47.2	59.2	0	8.8
Pl	Leuctra sp.		146.4	18.4	176	71.2	4	8	29.6	12.8	93.6	10.4	0	148	1.6	214.4	39.2	14.4	144	56	0	21.6
Pl	Perla burmeisteriana	CLAASSEN, 1936	0	0	0	0	0	0	0	0	3.2	0	0	0	0	0	3.2	3.2	0	32	0	0
Pl	Perla marginata	(PANZER, 1799)	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pl	Perlidae Gen. sp.		0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pl	Protonemura nitida-Gr.		0	2.4	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0
Pl	Protonemura sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0
He	Corixidae Gen. sp.		0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0
He	Gerris sp.		0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	1.6	0	0
Me	Sialis fuliginosa	PICTET, 1836	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	1.6	0	0
Me	Sialis lutaria	(LINNAEUS, 1758)	0	0	0	0	2.4	0	0	0.8	0	0	0	0	3.2	0	1.6	0	8	0	7.2	0
Me	Sialis nigripes	PICTET, 1865	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8
Me	Sialis sp.		0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0
Co	Brychius elevatus Lv.	(PANZER, 1794)	0	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Co	Elmis aenea Ad.	(MÜLLER, 1806)	0	2.6	4.8	0	78.2	0	0	10.4	2.8	0	0	0	0	0	0	0	0	0	0	1.7
Co	Elmis aenea/maugetii Ad.		10.4	0	0	0	0	0	0	0	0	0	0	0	0	3.5	0	0	0	0	0	0
Co	Elmis maugetii Ad.	LATREILLE, 1798	0	1.4	4.8	0	275.2	0	14.4	41.6	61.2	6.4	0	24	0	30.1	78.8	3.2	46.8	20.8	0	123.9
Co	Elmis rioloides Ad.	KUWERT, 1890	0	20.8	0	0	98.6	0	0	0	0	0	0	0	0	0	21.2	0	3.6	0	0	0
Co	Elmis sp. Ad.		0	0	0	0	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0

Taxa group	Taxon	Author	D0500012	D0500022	D0500032	D0500042	D0500052	D0500062	D0500072	D0500082	D0500092	D0500102	D0500112	D0500122	D0500132	D0500142	D0500152	D0500162	D0500172	D0500182	D0500192	D0500202
Co	Elmis sp. Lv.		4.8	20	8	23.2	114.4	3.2	6.4	28.8	8.8	2.4	0	10.4	0.8	23.2	70.4	17.6	24	17.6	0	30.4
Co	Esolus angustatus Ad.	(MÜLLER, 1821)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0
Co	Esolus parallelepipedus Ad.	(MÜLLER, 1806)	0	0	0	0	0	0	0	0	15.2	0	0	5.6	0.8	0	8	0	0.8	5.6	0	0
Co	Esolus sp. Lv.		0	0.8	1.6	0.8	0.8	0	0	0.8	12	0	0	3.2	1.6	0	0	2.4	4	3.2	0	0.8
Co	Haliplus sp. Ad.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0
Co	Haliplus sp. Lv.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17.6	0
Co	Helophorus brevipalpis Ad.	BEDEL, 1881	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0
Co	Hydraena dentipes Ad.	GERMAR, 1844	0	0	0	0	0.8	0	0	0	0	0	0	0	1.6	3.5	8.8	1.6	3.2	0.8	0	0
Co	Hydraena gracilis Ad.	GERMAR, 1824	2.4	1.6	6.4	3.2	0	1.6	4.8	2.4	2.7	0	0	6.4	0	31.4	0	0	4.8	4	0	3.7
Co	Hydraena reyi Ad.	KUWERT, 1888	0	0	0	0	0	0	0	0	1.3	0	0	0	0	3.5	0	0	0	1.6	0	1.9
Co	Hydraena sp. Ad.		0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0
Co	Hydroporinae Gen. sp. Lv.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
Co	Laccobius sp. Lv.		0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Co	Limnius opacus Ad.	MÜLLER, 1806	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0.8	0	0	1.6	0	1.6
Co	Limnius opacus Lv.	MÜLLER, 1806	0	0	0	0	0	0	0	0	14.4	0	0	0	0	0	38.4	0.8	0	0.8	0	2.4
Co	Limnius perrisi Lv.	(DUFOUR, 1843)	0	0.8	1.6	0.8	0	0.8	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0
Co	Limnius volckmari Ad.	(PANZER, 1793)	0	1.6	0	0.8	6.4	0.8	0	4.8	2.4	0	0	0.8	0	0.8	7.2	0	4	1.6	0	5.6
Co	Limnius volckmari Lv.	(PANZER, 1793)	0	0.8	5.6	16	9.6	0	0	42.4	4.8	0	0	1.6	0	4.8	3.2	0	2.4	3.2	0	16
Co	Nebrioporus depressus Ad.	(FABRICIUS, 1775)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	227.2	0
Co	Nebrioporus elegans Ad.	(PANZER, 1794)	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0.8	0	16.8	0
Co	Oulimnius tuberculatus Ad.	(MÜLLER, 1806)	4	0	0.8	0	156.8	1.6	0	4	1.6	0	0	0.8	0	1.6	4.8	0	3.2	1.6	0	4
Co	Oulimnius tuberculatus Lv.	(MÜLLER, 1806)	0.8	0	22.4	2.4	8	3.2	2.4	2.4	0.8	0.8	0	3.2	2.4	1.6	6.4	0.8	9.6	0.8	0	4
Co	Stenelmis canaliculata Ad.	(GYLLENHÅL, 1808)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.8	0	0	0	0	0
Co	Stenelmis canaliculata Lv.	(GYLLENHÅL, 1808)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10.4	0	0	0	0	0
Tc	Agapetus fuscipes	CURTIS, 1834	0	0	0	19.5	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	23.3
Tc	Agapetus ochripes	CURTIS, 1834	0	0	0	101.3	11.2	0	0	0	15.2	0	0	0	0	0	0	0	0	0	0	10.3
Tc	Allogamus auricollis	(PICTET, 1834)	0	0	0.8	0.8	0.8	2.4	0.8	12	0	0	0	0	0	83.2	0	0	16	8.8	0	33.6
Tc	Anabolia nervosa	(CURTIS, 1834)	0	0.8	4	0	0	0	0	0	0	0	0	0	0	4	0	0	9.6	0.8	0	0
Tc	Annitella obscurata	(McLACHLAN, 1876)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.6	0	0	0.8
Tc	Anomalopterygella chauviniana	(STEIN, 1874)	0	1.6	0	0	0	0	0	1.6	0	0	0	0	0	2.4	0.8	0	0	0.8	0	0

Taxa group	Taxon	Author	D0500012	D0500022	D0500032	D0500042	D0500052	D0500062	D0500072	D0500082	D0500092	D0500102	D0500112	D0500122	D0500132	D0500142	D0500152	D0500162	D0500172	D0500182	D0500192	D0500202
Tc	Athripsodes albifrons	(LINNAEUS, 1758)	0	0	16.8	100.8	0	1.6	0	0	12.8	0	0	0	0	0	12	15.2	6.4	8	0	3.6
Tc	Athripsodes bilineatus	(LINNAEUS, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	0.8	9.6	0.8	0	4.8	0	0	1.4
Tc	Athripsodes cinereus	(CURTIS, 1834)	0.8	0	0.8	0	0	0	0	0	4.8	0	0	0	0	0	4.8	0	0	3.2	0	1.4
Tc	Brachycentrus maculatus	(FOURCROY, 1785)	0	0	0	1168	3200	0	0	0	184	0	0	0	0	0	0	0	0	0	0	28.8
Tc	Brachycentrus subnubilus	CURTIS, 1834	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0	54.4	0	0.8	0.8	0	0
Tc	Ceraclea dissimilis	(STEPHENS, 1836)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.2	0	0	0	7.2	0
Tc	Chaetopteryx villosa	(FABRICIUS, 1789)	0	0	13.6	1.6	0	0	4.8	21.6	0	0	0	0	0.8	25.6	0.8	0	0	0	0	0
Tc	Cheumatopsyche lepida	(PICTET, 1834)	0	0	0	12	0.8	0	0	0	1.6	0	0	0	0	0.8	128	3.2	0	14.4	0	4.8
Tc	Chimarra marginata	(LINNAEUS, 1767)	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	17.6	0	0	0	0	0
Tc	Cyrnus trimaculatus	(CURTIS, 1834)	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Glossosoma sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8
Tc	Goera pilosa	(FABRICIUS, 1775)	0	0	0.8	0	0	1.6	0	0	2.4	0	0	0	0	0	0	0	0	0	0	0
Tc	Goeridae Gen. sp.		0	0	0	0	0	0	0	0.8	0	0.8	0	0	0.8	0	0	0	1.6	0	0	0.8
Tc	Halesus digitatus	(SCHRANK, 1781)	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0.8
Tc	Halesus radiatus	(CURTIS, 1834)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0
Tc	Halesus rubricollis	(PICTET, 1834)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8
Tc	Halesus tesselatus	(RAMBUR, 1842)	0	0	0	0	0.8	1.6	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0.8
Tc	Hydropsyche dinarica	MARINKOVIC, 1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0.8
Tc	Hydropsyche incognita	PITSCH, 1993	2.4	8	0	70.4	1.6	3.2	34.4	0	49.6	47.2	0	22.4	0	0	2.4	72.8	0	0.8	0	23.2
Tc	Hydropsyche instabilis	(CURTIS, 1834)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.6	0.8	0	0
Tc	Hydropsyche pellucidula	(CURTIS, 1834)	0	2.4	0	0	0	8	0	0	0	0	0	0	0	0	0	13.6	58.4	0.8	0	5.6
Tc	Hydropsyche siltalai	DÖHLER, 1963	80	331.2	58.4	13.6	11.2	3.2	0	15.2	4.8	8	0	3.2	0	78.4	210.4	17.6	0	31.2	0	3.2
Tc	Hydropsyche sp.		13.6	8	2.4	185.6	29.6	5.6	120	12.8	130.4	33.6	0	64.8	0.8	38.4	15.2	184	240	72	0	83.2
Tc	Hydroptila sp.		0	0	0.8	4	0	0.8	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Lepidostoma hirtum	(FABRICIUS, 1775)	8.8	9.6	8.8	5.6	8.8	3.2	4.8	0	0	0	0	0.8	0.8	0	35.2	3.2	19.2	1.6	0	5.6
Tc	Leptoptilus crumeniferus	(LINNAEUS, 1761)	0	1.6	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0.8	0	0	0
Tc	Leptoceridae Gen. sp.		0	0	0	0	0	0	0	0.8	0	0	0	0	0.8	0	0.8	0	2.4	0	0	0
Tc	Limnephilidae Gen. sp.		0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Micrasema longulum	McLACHLAN, 1876	1.6	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Micrasema minimum	McLACHLAN, 1876	30.4	92.8	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32

Taxa group	Taxon	Author	D0500012	D0500022	D0500032	D0500042	D0500052	D0500062	D0500072	D0500082	D0500092	D0500102	D0500112	D0500122	D0500132	D0500142	D0500152	D0500162	D0500172	D0500182	D0500192	D0500202
Tc	Micrasema setiferum	(PICTET, 1834)	0	0	0	0	40	0	0	0	0	0	0	0	0	0	5.6	1.6	0	0	0	0
Tc	Mystacides azurea	(LINNAEUS, 1761)	0	1.6	0	0	0.8	4.8	5.6	0	0	0	0.8	0	0	0	1.6	0	0	0	0	0
Tc	Mystacides longicornis	(LINNAEUS, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6	0	0	0	0	0
Tc	Mystacides nigra	(LINNAEUS, 1758)	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0.8	0	0	0	0	0	0
Tc	Odontocerum albicorne	(SCOPOLI, 1763)	0	0	8	0.8	1.6	0	0	37.6	0	0	0	0	0	0	0	0	0	3.2	0	0
Tc	Oecetis notata	(RAMBUR, 1842)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.4	0	0	0	0	0
Tc	Oecetis testacea	(CURTIS, 1834)	1.6	14.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Philopotamus montanus	(DONOVAN, 1813)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8
Tc	Philopotamus sp.		0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0
Tc	Polycentropus flavomaculatus	(PICTET, 1834)	27.2	33.6	8	5.6	18.4	15.2	0	5.6	15.2	0	0	5.6	1.6	0	80	36	16	28.8	0	29.6
Tc	Potamophylax luctuosus	(PILLER & MITTERPACHER, 1783)	0	0	0	0	3.2	0	0	0	0	0	0	0	0	1.6	0	0	0	0	0	0
Tc	Potamophylax rotundipennis	(BRAUER, 1857)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0
Tc	Psychomyia pusilla	(FABRICIUS, 1781)	0	0	9.6	72	24	4.8	4	0	4.8	14.4	0	2.4	0	0	8.8	5.6	1.6	0	0	4.8
Tc	Rhyacophila dorsalis	(CURTIS, 1834)	6.2	12.4	1	28.8	9.6	0	35.2	34	45.5	0	0	0	0	0	0	0	0	0	0	78.7
Tc	Rhyacophila fasciata	HAGEN, 1859	33.5	12.4	3	32	14.4	0	0	1.2	12.5	0	0	1.6	0	1.4	0	0	0	0	0	19.7
Tc	Rhyacophila nubila	(ZETTERSTEDT, 1840)	0	0	0	0	0	0	0	0	0	137.6	0	106.6	0	117.8	98.4	88	146.4	92	0	0
Tc	Rhyacophila sp.		0	0	0	0	0	0	0	0	0	0	0	0	3.2	0	0	0	0	0	0.8	0
Tc	Sericostoma flavicorne	SCHNEIDER, 1845	0	0	0	0.8	1.6	0	0	0	0	0	0	0	0.8	0	0	0	0.8	0	0	0
Tc	Sericostoma sp.		24	80	6.4	79.2	6.4	15.2	12.8	31.2	2.4	0	0	0	4.8	69.6	0	6.4	12	28.8	0	19.2
Tc	Silo piceus	(BRAUER, 1857)	0.8	0	0	0.8	0	1.6	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0
Tc	Silo sp.		0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Tinodes waeneri	(LINNAEUS, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.2	0
Di	Atherix sp.		0.8	1.6	0	0	0.8	0	5.6	0.8	0.8	2.4	0	1.6	1.6	46.4	3.2	4.8	12.8	23.2	2.4	3.2
Di	Berdeniella sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	1.6	0	0	0	0	0	0
Di	Ceratopogonidae Gen. sp.		0.8	0	0	0	0	0	0	0	0	1.6	0	0	0	0.8	0.8	0.8	5.6	1.6	0	0
Di	Chironomidae Gen. sp.		0	3.2	0.8	15.2	11.2	25.6	19.2	3.2	9.6	4	68.8	30.4	78.4	4.8	10.4	4	9.6	12.8	12.8	16.8
Di	Chironomini Gen. sp.		76.8	0.8	172	80	84.8	422.4	297.6	125.4	175.2	26.4	54.4	365.6	3052	54.4	115	0	1200	297.6	367.2	384.6
Di	Cylindrotomidae Gen. sp.		0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0
Di	Diamesinae Gen. sp.		0	0	0	8	0	0	17.6	0	0	0	0	0.8	0	97.6	0	9.6	21.6	0	2.4	2.4
Di	Dicranota sp.		0	0	16.8	0	8	0	0.8	12.8	14.4	0	0	33.6	0	48.8	0	4	33.6	36.8	0	0.8

Taxa group	Taxon	Author	D0500012	D0500022	D0500032	D0500042	D0500052	D0500062	D0500072	D0500082	D0500092	D0500102	D0500112	D0500122	D0500132	D0500142	D0500152	D0500162	D0500172	D0500182	D0500192	D0500202
Di	Empididae Gen. sp.		0	0	0.8	0	0	0	0	0.8	0	0	0	0.8	0	0	0	0	0.8	0.8	0.8	0
Di	Eutonia sp.		12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Di	Ibisia marginata	(FABRICIUS, 1781)	2.4	0.8	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0
Di	Liponeura sp.		0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Di	Orthocladiinae Gen. sp.		23.2	37.6	582.4	173.6	106.4	20	24.8	37.6	39.2	85.6	68.8	62.4	33.6	11.2	72	14.4	43.2	52	6.4	86.4
Di	Pedicia sp.		31.2	0	4.8	26.4	50.4	11.2	29.6	4	0	12.8	0	0	0	0	4	17.6	0.8	0	0	0
Di	Pericoma sp.		0	0	0	0	0	0	0	0	0	0	0	0	2.4	0	0	0	0	0	0	0
Di	Prionocera sp.		0	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Di	Prodiamesinae Gen. sp.		0	0	0	0	0	0.8	0	44.8	0.8	0	265.6	0	0	0	0	0	0	0	0	0.8
Di	Prosimulium sp.		0	0	0	0	5.6	0	0	20	9.6	0	0	0	0	0	0.8	1.6	0	0	0	0
Di	Psychodidae Gen. sp.		0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0
Di	Ptychopteridae Gen. sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0
Di	Rhagionidae Gen. sp.		4	57.6	10.4	0	11.2	8	28	24.8	7.2	0	0	0	0	4.8	34.4	92.8	0	0	0	0
Di	Simulium argyreatum	MEIGEN, 1838	0	12	7.2	0	2.4	0	0	0	0	0	0	0	0	4.8	0	0	0	0	0	0
Di	Simulium costatum	FRIEDERICHS, 1920	0	0	0.8	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Di	Simulium erythrocephalum	(DE GEER, 1776)	0.8	0	0	4	0	0	0	7.2	0	0	0	0	0	0	0	0	1.6	0	0	0
Di	Simulium lineatum	(MEIGEN, 1804)	0	0	0	0	0	0	0	0	0	9.6	0	0	0	0	0	0	0	2.4	0	0
Di	Simulium ornatum	MEIGEN, 1818	0	0	0	6.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Di	Simulium ornatum-Gr.		1.6	0	7.2	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	7.2
Di	Simulium paramorsitans	RUBZOV, 1956	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0
Di	Simulium sp.		10.4	32	68	58.4	47.2	1.6	31.2	79.2	44.8	21.6	0	5.6	0	38.4	74.4	79.2	36	9.6	0	42.4
Di	Tanypodinae Gen. sp.		44.8	10.4	136	24	20	6.4	12.8	23.2	22.4	60.8	96	46.4	67.2	7.2	71.2	16	49.6	86.4	24	12
Di	Tanytarsini Gen. sp.		3.2	4.8	6.4	1.6	21.6	64	53.6	25	2.4	44.8	4.8	131.2	179.2	41.6	37	16	110.4	37.6	17.6	33
Di	Tipula maxima-Gr.		0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Di	Tipula sp.		0	0	0	0	0	0	0	0	0	0.8	8	10.4	0	0	0	0	0	0	0	0

Appendix 8. Taxa list of the summer samples of the large streams in lower mountainous areas of Germany (stream type 9.2) (Ind/m^2). (Bi = Bivalvia, Co = Coleoptera, Cr = Crustacea, Di = Diptera, Ep = Ephemeroptera, Ga = Gastropoda, He = Heteroptera, Hi = Hirudinea, Me = Megaloptera, Ne = Nematomorpha, Od = Odonata, Ol = Oligochaeta, Pl = Plecoptera, Tr = Trichoptera,Tu = Turbellaria)

Taxa group	Taxon	Author	D1000012	D1000022	D1000032	D1000062	D1000072	D1000082	D1000092	D1000102	D1000112	D1000122	D1000132	D1000152	D1000162
Tu	Turbellaria Gen. sp.		0	0	0	5.8	0	4.8	0	24.8	0	9.6	0	0	0
Ga	Ancylus fluviatilis	O.F. MÜLLER, 1774	4.8	0	0	153.6	17	19.2	14.4	0	0	38.4	25.6	0	9.6
Ga	Bithynia tentaculata	(LINNAEUS, 1758)	0	0	0	0	4	4.8	0	48	24	4.8	0	0	0
Ga	Potamopyrgus antipodarum	(GRAY, 1843)	0	0	0	0	0	0	0	0.8	0	0	0	0	0
Ga	Radix sp.		0	0	0	0	4	0	0	0	0	0	0	4.8	0
Ga	Theodoxus fluviatilis	(LINNAEUS, 1758)	0	0	0	0	2	0	2.9	43.2	0	0	0	0	0
Bi	Pisidium sp.		4.8	4	0	4.8	16	57.6	2.9	52.8	9.6	14.4	3.2	9.6	9.6
Bi	Sphaerium sp.		28.8	0	0	4.8	0	18.4	0	148.8	28.8	9.6	0	0	4.8
Ne	Gordius aquaticus	(LINNAEUS, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	4.8
Ol	Oligochaeta Gen. sp.		4.8	28	4.8	163.2	8	48	22.6	115.2	52.8	86.4	0.8	100.8	14.4
Hi	Erpobdella sp.		0	4	4.8	100.8	0	4.8	0	0	0	0.8	3.2	7.2	0
Hi	Glossiphonia sp.		4.8	0	0	14.4	0	0	0	0	0	0	0	0	0
Hi	Helobdella stagnalis	(LINNAEUS, 1758)	1	0	0	0	0	0	0	0	0	0	0	4.8	0
Hi	Piscicola sp.		5.8	1	1	0	4	0	0	0.8	0	4.8	0	0	5.6
Cr	Asellus aquaticus	(LINNAEUS, 1758)	19.2	4	29.8	14.4	8	9.6	0	0.8	0	48	4	0	4.8
Cr	Gammarus fossarum	KOCH in PANZER, 1836	0	0	19.2	0	124	1	170.6	43.2	0	33.6	0	0	4.8
Cr	Gammarus pulex	(LINNAEUS, 1758)	4.8	0	0	28.8	0	0	0	0	0	9.6	38.4	58.4	0
Cr	Gammarus roeselii	(GERVAIS, 1835)	480	20	0	0	0	143.2	0	159.2	1401.6	1089.6	0	322.4	144
Cr	Proasellus coxalis	(DOLLFUS, 1892)	0	0	0	0	0	0	0	0	28.8	0	0	0	0
Ep	Baetis alpinus-Gr.		0	0	0	0	0	0	8.2	0	0	0	14.4	0	4.8
Ep	Baetis buceratus	EATON, 1870	0	0	0	0	0	0	2.1	0	0	0	4.8	0	0
Ep	Baetis fuscatus	(LINNAEUS, 1761)	48	62	269.8	10.6	10	297.6	37.2	57.6	1003.2	259.6	224.8	130.4	223.2
Ep	Baetis liebenauae	KEFFERMÜLLER, 1974	0	0	0	0	0	0	0	9.6	0	0	0	0	59.2
Ep	Baetis lutheri	MÜLLER-LIEBENAU, 1967	0	0	0	0	0	0	0	0	0	0	0	4.8	0
Ep	Baetis rhodani	PICTET, 1843-1845	4.8	8	0	46.4	63	0	2.1	5.6	0	86.4	11.2	28.8	19.2

Taxa group	Taxon	Author	D1000012	D1000022	D1000032	D1000062	D1000072	D1000082	D1000092	D1000102	D1000112	D1000122	D1000132	D1000152	D1000162
Ep	Baetis scambus	EATON, 1870	0	8	0	77	0	0	0	0	0	105.2	4.8	9.6	0
Ep	Baetis sp.		111.4	364	576	411	40	422.4	121.3	28.8	33.6	351.2	120	28.8	62.4
Ep	Baetis vardarensis	IKONOMOV, 1962	0	0	0	0	0	0	0	0	67.2	0	39.2	0	0
Ep	Baetis vernus	CURTIS, 1834	0	0	0	2	6	0	30.8	20	0	85.6	3.2	24	0
Ep	Centroptilum luteolum	(MÜLLER, 1776)	0	0	0	0	0	0	4.1	0	0	0	0	0	0
Ep	Caenis beskidensis	SOWA, 1973	0	0	0	0	0	0	0	0	0	0	0	4.8	0
Ep	Caenis luctuosa	(BURMEISTER, 1839)	19.2	0	19.2	0	12	0	0	0	120	4.8	1.6	0	24
Ep	Caenis macrura	STEPHENS, 1835	4.8	0	0	0	0	0	0	0	4.8	0	6.4	0	0
Ep	Caenis rivulorum	EATON, 1884	0	0	0	9.6	0	0	0	0	0	0	0	0	0
Ep	Serratella ignita	(PODA, 1761)	809.6	112	110.6	595.6	612	158.6	97.9	1585.6	172.8	3940.8	107.2	1892.8	1096
Ep	Torleya major	KLAPÁLEK, 1905	0	0	0	0	0	0	0	0	4.8	0	0	0	0
Ep	Ephemera danica	MÜLLER, 1764	20.2	5	0	0	0	0	0	10.4	57.6	0	0	0	5.6
Ep	Ecdyonurus dispar	(CURTIS, 1834)	0	0	12	8	2	10.6	0.8	0	4.8	0	0	0	0
Ep	Ecdyonurus insignis	(EATON, 1870)	0	0	4	0	0	0	0	0	9.6	0	0	0	0
Ep	Ecdyonurus sp.		0	0	28.8	4.8	2	10.6	2.1	0	33.6	0	0	9.6	0
Ep	Ecdyonurus venosus-Gr.		0	0	4.8	0	5	0	0	0	0	0	0	0	0
Ep	Electrogena sp.		0	0	1	0	0	4.8	0.8	0	0	0	0	0	0
Ep	Heptagenia longicauda	(STEPHENS, 1836)	0	0	0	0	0	0	0	0	0	0.8	0	0	0
Ep	Heptagenia sp.		4.8	1	0	9.6	0	0	0	0	0	0	0	0	19.2
Ep	Heptagenia sulphurea	(MÜLLER, 1776)	2	2	0	0	4	1	0	0	0	109.6	0	0	15.2
Ep	Rhithrogena beskidensis	ALBA-TERCEDOR & SOWA, 1987	0	0	0	0	0	0	0	0	0	68	0	0	0
Ep	Rhithrogena sp.		0	0	0	0	0	0	0	0	0	19.2	0	0	0
Ep	Oligoneuriella rhenana	(IMHOFF, 1852)	71.2	347	0	0	0	0	4.5	0	0	0	0	0	142.4
Ep	Potamanthus luteus	(LINNAEUS, 1767)	17.4	0	30.2	0	0	43.6	0	0.8	0	0	0	0	28.8
Od	Calopteryx splendens	(HARRIS, 1782)	9.6	0	0	0	0	0	0	0	4.8	0	0	0	0
Pl	Leuctra geniculata	(STEPHENS, 1836)	0	0	5.8	19.2	0	12.6	0	0	249.6	0.8	1.6	0	0
Pl	Leuctra sp.		9.6	36	52.8	363	12	68.2	0	9.6	24	172.8	13.6	72	19.2
Pl	Perla burmeisteriana	CLAASSEN, 1936	0	0	0	1	0	0	0	0	0	0	0	0	0
Pl	Isoperla sp.		1	0	0	0	0	0	0	0	0	0	0	0	0
He	Aphelocheirus aestivalis	(FABRICIUS, 1794)	183.4	1	0	0	0	67.2	22.6	73.6	9.6	0	23.2	0	197.6

Taxa group	Taxon	Author	D1000012	D1000022	D1000032	D1000062	D1000072	D1000082	D1000092	D1000102	D1000112	D1000122	D1000132	D1000152	D1000162
He	Corixidae Gen. sp.		0	4	0	0	0	0	0	0	0	0	0	0	0
He	Gerris sp.		0	0	1	0	0	0	0	0	0	0	0	0	0
He	Nepa cinerea	LINNAEUS, 1758	0	0	0	0	0	0	0	0	0	0	0	0.8	0
Me	Sialis lutaria	(LINNAEUS, 1758)	0	0	0	14.4	0	0	0	0	0	0	0	0	0
Co	Platambus maculatus Ad.	(LINNAEUS, 1758)	0	1	0	0	0	0	0	0	0	0	0	0	0
Co	Nebrioporus elegans Ad.	(PANZER, 1794)	0	0	0	0	0	0	0	0	0	0	0	1.6	0
Co	Oreodytes sanmarkii Ad.	(SAHLBERG, 1834)	0	0	0	1	0	0	0	0	0	0	0	0	0
Co	Elmis aenea/maugetii Ad.		41.4	53	4.8	434.2	146	118.2	266.7	350.4	33.6	24	56	298.4	76.8
Co	Elmis rioloides Ad.	KUWERT, 1890	0	0	0	0	0	0	37	0	0	0	0	0	0
Co	Esolus parallelepipedus Ad.	(MÜLLER, 1806)	0	4	19.2	0	0	14.4	124.1	0	0	0	0	0	0
Co	Esolus pygmaeus Ad.	(MÜLLER, 1806)	0	0	0	0	0	0	0	0	9.6	0	0	0	0
Co	Esolus sp. Lv.		0	4	49	0	0	48	69.9	0	4.8	0	0	0	0
Co	Limnius opacus Ad.	MÜLLER, 1806	0	0	19.2	0	4	0	0	0	0	0	0	0	0
Co	Limnius volckmari Ad.	(PANZER, 1793)	52.4	269	14.4	276.6	121	28.8	149.6	86.4	28.6	19.2	9.6	0	129.6
Co	Normandia nitens Ad.	(MÜLLER, 1817)	0	0	0	0	0	0	0	0	4.8	0	0	0	0
Co	Oulimnius tuberculatus Ad.	(MÜLLER, 1806)	28.8	40	24	9.6	28	214.2	33.7	48	62.4	0	24	0	101.6
Co	Riolus sp. Lv.		0	0	0	0	0	0	10.3	4.8	0	0	0	0	0
Co	Stenelmis canaliculata Ad.	(GYLLENHÅL, 1808)	0	0	44.2	0	0	0	0	0	24	0	0	0	0
Co	Orectochilus villosus Ad.	(MÜLLER, 1776)	0	0	1	0	0	0	0	0	0	0.8	0	0	0
Co	Hydraena gracilis Ad.	GERMAR, 1824	4.8	12	9.6	9.6	0	0	2.1	0	0	14.4	1.6	5.6	0
Tc	Brachycentrus maculatus	(FOURCROY, 1785)	0	0	0	0	0	0	47.3	0	0	0	0	0	0
Tc	Brachycentrus montanus	KLAPALEK, 1892	300.8	8	0	0	0	0	0	0	0	0	0	0	0
Tc	Brachycentrus subnubilus	CURTIS, 1834	456.8	20	0	55.8	182	9.6	0	189.6	0	0	0	15.2	281.6
Tc	Agapetus ochripes	CURTIS, 1834	0	0	0	44.2	4	4.8	14.4	0	0	0	0	0	0
Tc	Goera pilosa	(FABRICIUS, 1775)	0	0	0	0	0	4.8	0	0	0	0.8	0	0	0
Tc	Cheumatopsyche lepida	(PICTET, 1834)	58.6	0	9.6	69.2	0	0	2.9	610.4	43.2	16	17.6	0	103.2
Tc	Hydropsyche contubernalis	McLACHLAN, 1865	0	0	5.8	0	0	0	0	0	0	0	0	0	0
Tc	Hydropsyche incognita	PITSCH, 1993	0	0	6.8	0	0	6.8	0	4.8	4.8	0	1.6	0	0
Tc	Hydropsyche pellucidula	(CURTIS, 1834)	0	0	20.2	14.4	0	19.2	0	0	0	0	0	0	0
Tc	Hydropsyche siltalai	DÖHLER, 1963	36.6	0	0	20.4	3	0	0	9.6	14.4	14.4	7.2	36	22.4

Taxa group	Taxon	Author	D1000012	D1000022	D1000032	D1000062	D1000072	D1000082	D1000092	D1000102	D1000112	D1000122	D1000132	D1000152	D1000162
Tc	Hydropsyche sp.		9.6	8	68.2	24	3	76.8	8.2	14.4	225.6	14.4	72	36	4.8
Tc	Hydroptila sp.		9.6	8	4.8	0	0	4.8	0	0	4.8	0	0	0	0
Tc	Lasiocephala basalis	(KOLENATI, 1848)	0	0	0	0	0	0	1.6	0	0	10.4	0	0	0
Tc	Lepidostoma hirtum	(FABRICIUS, 1775)	299.6	8	0	44.2	7	0	2.1	4.8	38.4	43.2	0	120.8	48.8
Tc	Athripsodes albifrons	(LINNAEUS, 1758)	10.8	86	0	39.4	0	25	17.2	10.8	30	84	3.2	192.8	52.8
Tc	Athripsodes bilineatus	(LINNAEUS, 1758)	0	0	0	0	18	0	0	9.2	0	0	0	0	0
Tc	Athripsodes cinereus	(CURTIS, 1834)	85.6	15	0	4.8	16	0	0	0	0	29.6	1.6	0	11
Tc	Ceraclea sp.		0	0	0	0	0	0	0	4.8	0	0	0	0	0
Tc	Mystacides azurea	(LINNAEUS, 1761)	0	0	5.8	0	0	4.8	0	0	0	0	0	0	0
Tc	Mystacides longicornis/nigra		0	0	0	0	7	0	0	0	0	0	0	0	0
Tc	Oecetis notata	(RAMBUR, 1842)	4.8	0	0	0	0	0	0	0	18.4	0	0	0	5.6
Tc	Oecetis testacea	(CURTIS, 1834)	4.8	0	0	0	0	0	0	0	0	0	0	0	0
Tc	Anabolia nervosa	(CURTIS, 1834)	0	0	0	3	0	0	0	0	0	0	0	0	0
Tc	Chaetopteryx villosa	(FABRICIUS, 1789)	0	0	0	10.6	0	0	0	0	0	0	0	0	0
Tc	Halesus radiatus	(CURTIS, 1834)	0	0	0	4.8	0	0	0	0	0	0	0	0	0
Tc	Potamophylax luctuosus	(PILLER & MITTERPACHER, 1783)	0	0	0	9.6	0	0	0	0	0	0	0	0	0
Tc	Odontocerum albicorne	(SCOPOLI, 1763)	0	0	0	4.8	0	0	0	0	0	0	0	0	0
Tc	Polycentropus flavomaculatus	(PICTET, 1834)	0	0	0	68.2	0	19.2	0	0	33.6	0	6.4	0	0
Tc	Lype reducta	(HAGEN, 1868)	0	0	0	0	0	0	0	0	0	4.8	0	0	0
Tc	Psychomyia pusilla	(FABRICIUS, 1781)	4.8	4	4.8	9.6	8	48	31.2	9.6	19.2	59.2	14.4	19.2	11.2
Tc	Rhyacophila fasciata	HAGEN, 1859	0	0	4.8	0	0	0	0	0	0	0	0	0	0
Tc	Rhyacophila nubila	(ZETTERSTEDT, 1840)	10.6	4	6	29.8	1	22.2	0	0	0	4.8	0	10.4	0.8
Tc	Rhyacophila obliterata	McLACHLAN, 1863	0	0	0	4.8	0	0	0	0	0	0	0	0	0
Tc	Rhyacophila sp.		10.6	4	4.8	6.8	1	22.2	8.2	9.6	9.6	4.8	9.6	9.6	0.8
Tc	Sericostoma sp.		0	0	0	82.6	4	0	4.5	0	0	0	0	0	0
Di	Atherix ibis	(FABRICIUS, 1798)	0	0	4.8	5.8	0	29.8	22.6	0	38.4	0	8	0.8	0
Di	Atrichops crassipes	(MEIGEN, 1820)	0	0	0	0	0	0	0.8	0	0	0	0	0	0
Di	Ceratopogonidae Gen. sp.		0	0	4.8	0	0	0	0	0	0	9.6	0	0	0
Di	Chironomidae Gen. sp.		86	244	1667.6	984	96	279.4	261.1	279.2	254.4	169.6	195.2	345.6	57.6
Di	Dolichopodidae Gen. sp.		0	0	4.8	0	0	0	0	0	0	0	0	0	9.6

Taxa group	Taxon	Author	D1000012	D1000022	D1000032	D1000062	D1000072	D1000082	D1000092	D1000102	D1000112	D1000122	D1000132	D1000152	D1000162
Di	Empididae Gen. sp.		0	0	0	0	0	0	0	0	0	0	0	4.8	0
Di	Antocha sp.		0	0	0	0	8	28.8	17.2	19.2	168	4.8	0	0	0
Di	Limnophora sp.		0	0	0	0	0	0	2.1	0	0	0	0	0	0
Di	Dicranota sp.		9.6	41	0	14.4	4	48	5.7	4.8	0	9.6	0	19.2	9.6
Di	Simulium sp.		1056	772	471.4	295.8	48	2463.4	41.1	91.2	0	124.8	152.8	0	2445.6
Di	Tipula maxima-Gr.		0	0	0	0	0	4.8	0	0	0	0	0	4.8	0